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CONTENTS

LEADING ARTICLES—
Too Much Talk and Colcutt 181
Courses in Technical Illustration ... 182
Conclusions from Road Research ... 182

ARTICLES—
Anglo-German Atomic Energy Agreement 183
British and German Export Competition 202
Calculation of Backlash Between Gear-Teeth. (Illus.) 190
Control System Nomogram. (Illus.)... 195
Cunard Liner "Carinthia." (Illus.) ... 199
Cut-Offs in Modern Hydraulic Diversion Works on Alluvial Rivers. No. I. (Illus.) 184
Electrical Equipment for Malting Plant in Nairobi. (Illus.)... 204
Engravings of 1874... 198
Further French Locomotive Experiences No. I. (Illus.) 188
High Temperature Circulating Pumps. (Illus.) 203
Institute of Physics 183
Lloyd's Shipbuilding Returns 183
Modern Pyrite Plant Opened in South Australia 205
Multi-Spindle Automatic Lathe. (Illus.) 207
Ramjet Engine. (Illus.)... 203
Royal Naval Surveying Service 204
Speed with Safety 183
Theory of Restrained Corrugated Diaphragms. (Illus.) 193
Tonnage Oxygen Plant Opened at Margam 183
Vacuum Gauge. (Illus.) 205
100 Years Ago... 183

CONTINENTAL SECTION—
Machining of Turbine Casings. (Illus.) 208
Medium Horsepower Diesel Engine. (Illus.) 208
Forthcoming German Engineers' Meetings 209
High Voltage Transmission Lines in Sweden 209
Convention of Chemical Science 209
Annual Report of a Hamburg Oil Company 209
German Tanker Line 209

AMERICAN SECTION—
Forward Scatter of Wireless Waves ... 210

LETTERS AND LITERATURE 196

LETTERS TO THE EDITOR—
Kariba Dam 196
London's Water Supply 196

LITERATURE 197

NEWS AND NOTES—
British Patent Specifications. (Illus.)... 215
British Standards Institution 195
Forthcoming Engagements 216
Industrial and Labour Notes 206
Launches and Trial Trips 216
Personal and Business 214
Technical Reports 216

TOO MUCH TALK AND COLCUTT

Do we all talk and write too much ? Do engineers as well as politicians and professors, lawyers and doctors, sports-writers and all the rest have far too much to say ? There is no difficulty in making out a case. All of us, for example, find our desks flooded with technical literature, technical reports and memoranda of all kinds. None of us can possibly read all that, perhaps, we should. Much of the material, judging by the small fraction that we do read, will contain information that we ought to have. But so often it is buried beneath so many platitudes and so much that is irrelevant that it is a laborious and time-wasting exercise to find it. Do we often blind ourselves by too much discussion? Does not talking often prove an anodyne for action ? Would it be very naughty to ask whether in basic essentials the Government's present plans for the development of technological education differ very much from those originated some ten years ago ? What good then has ten years' talk done except to provoke delay ? Then there was all the business before the war about the development of water power in Scotland. Glen power for glen people ; that or something like it became the indignant cry. It did not and could not stop the eventual development of Scottish water power resources. But how much all the talk delayed it ! Again, for the last two years hardly a month has passed without an article being published, a paper delivered, a conference held or a statement made on automation. But far from preparing people for some of the consequences it acted as an anodyne ; it suggested that automation would come so slowly that there was no need to worry unduly about labour reactions. So no one was prepared for labour troubles when they developed. Even technically too much talk can sometimes do harm. What enthusiasm was engendered after the war for the industrial gas turbine. What fine prospects it seemed to have ! How many firms, we wonder, got their fingers burnt in that particular pie ?

Yet what is the alternative ? For too little talk can have consequences just as bad ; and who is to settle what is enough and no more than enough ? Would there have been all that trouble about the dumping of some almost innocent radio-active waste products down a disused mine in the Forest of Dean if the public had been fully informed ? Instead there was issued through a heavy veil of secrecy just enough information to frighten people of radioactive perils and not nearly enough to reassure them. Failure abundantly to inform and consult as, for example, in introducing new machinery into a factory can breed bitter resistance when, at the cost of talking, co-operation could easily have been ensured. Would the public have as much faith in the safety of trains, ships and aircraft if inquiries into accidents were held in secret instead of openly for all to comment ? Dirty linen, it is claimed, is best not washed in public. But washed in public, it comes out so very much the cleaner ! How wise are firms whose products have met with serious failures to arrange for open publication of all the details and all that is being done to prevent a recurrence. The attempt to hush it up merely breeds exaggerated rumours. Usually the limit of the harm that can be done by too much talk is the enforcement of aggravating and unnecessary delay. There are scarcely any limits to the harm that too little talk may do. Secrecy can be used not only for security, but to cover up inefficiency. Bureaucracy and its oppressions flourish mightily only where there is a censorship on free speech.

But in some fields of human action we do verily believe that too much talk can lead to erroneous conclusions. A few men acting together can study a subject more exhaustively than can the mass. Their conclusions are more likely to be right than any based on attempts to "integrate" the views of all. The business of the Colcutt tower is a case in point. To permit an expansion of the Imperial College of Science and Technology in London it was originally proposed entirely to demolish the Imperial Institute building erected to Colcutt's designs less than a century ago. That proposal aroused objections. In particular it has been argued that the high tower arising above that building makes an attractive addition to London's skyline. Under present proposals the compromise has been adopted that a substantial modification be made in the original modernistic plans for the development of the area and that the tower be preserved,

free-standing in a courtyard. That is a compromise that can satisfy nobody. But it may be suggested that compromises never do. Nonsense! Many a compromise has been deeply satisfying to a vast majority suspicious of extreme opinions. But here that majority does not exist. There are here only two logical alternatives, wholly to preserve or wholly to demolish Colcutt's building. There is no logic about the retention of a useless tower. Nor is there logic in making free-standing a tower designed to rise from a surrounding group of high buildings. The compromise serves only the purpose of stifling a conflict at the cost of sacrificing a modernistic plan far more satisfactory than the one which is to replace it. Surely in this matter there has been too much talk? Or has there been too little? Is the present decision irrevocable? If it is there is but one hope left. It is that upon examination it will be found that the tower standing nakedly alone will prove to be unstable. We hope so. We profoundly hope so!

COURSES IN TECHNICAL ILLUSTRATION

It is good news that the City and Guilds of London Institute has produced regulations and a syllabus for courses in technical illustration. For, in answer to an increasing demand for technical illustrators, a number of colleges had already put on courses devised by themselves; yet there was neither unanimity as to what such a course should contain nor any clearly recognisable award by which the quality of a successful student could be judged. The course that has been devised is envisaged by the Institute as a five-year part-time one, requiring attendance for eight hours a week. It is intended to cover the needs of "apprentices and learners who are training to become technical artists in industry, government service and technical art studios." There will be an intermediate examination at the end of the third year and a final examination at the end of the course, intermediate and final "certificates" being awarded for satisfactory performance. The intermediate examination will be held for the first time in 1957 and the final for the first time in 1958.

It may not be appreciated by all engineers how important the work of technical illustrators is becoming. A clear distinction must be drawn between the technical illustrator and the commercial artist, whose primary concern lies with advertising. The former, starting from working drawings, should be capable of producing accurate perspective cut-away and similar illustrations, diagrams of various kinds such as those showing, for example, lubrication circuits, and many other illustrative works, intended for instructional books, manuals, maintenance handbooks, catalogues, textbooks and the like, in line, wash and colour techniques. To date not very many industries have taken a deep interest in works of that character. Probably the chief demands for illustrators at present come from the aircraft and motor vehicle industries, both of which find it profitable to publish very fine examples of the work of illustrators, and from the Services. But the trend towards the improvement of the literature sent out by engineering firms is very likely to lead to an increasing demand for technical illustrators.

It is a necessary corollary of an expansion in the demand for technical illustrators that there must also be an expanding demand for technical writers. Though the Institute is not yet contemplating devising a suitable course, activities are in train elsewhere which may well lead eventually to the Institute becoming interested. Devising a suitable course might well prove more difficult in that subject than in technical illustration. For the range of technical writing extends from the simply descriptive, requiring much practical but little academic knowledge, to the highly theoretical and technical, which could hardly be composed by anyone beneath degree standard. It might prove impossible to devise a single course that would prove valuable to such diverse qualities of minds.

CONCLUSIONS FROM ROAD RESEARCH

It is always stimulating to read the annual reports of the Road Research Laboratory. That organisation sets an example in the clarity with which it expounds seemingly simple solutions to the problems it has investigated. The 1955 report was published last week. Over the years, part of the work of the Laboratory's "materials and methods of construction" division has been accepted as the basis of standard practice; with the progress expected on several full-scale trials, which have been planned for some time now and which have been awaiting opportunities for their execution, the division's influence on the further development of more scientific and more economical design procedures should increase even more. The results of the "traffic and safety" division's work are of national importance. Some of these studies should be known to all drivers of cars, and might well be reprinted and circulated widely.

Road safety and road construction is now a problem in the forefront of the nation's domestic affairs. Therefore, even though the Laboratory's report contains such a wealth of detailed information, it is even more gratifying to observe that the Road Research Board has not hesitated to draw the broad conclusion from all this work, in a forthright manner. The Board refers first to increases in traffic—the increase between 1954 and 1955 was double the corresponding increase in the previous year, and in the busiest month of 1955 (July) traffic was 30 per cent above the corresponding figures for 1954—and then goes on to say: "Welcome as the growth in traffic may be as a sign of national prosperity, it can be viewed only with grave disquiet by those who have to face the hazards, frustrations and economic losses that result from the present limited capacity of the country's road system. The outlook is worsened by the knowledge gained from our investigations that beyond a certain measure of congestion—now reached at many points—small increases in traffic cause delays to multiply at a rapidly increasing rate. Whilst, therefore, we are glad to note that the Government has agreed that the present programme of road construction is to proceed despite general restrictions in capital expenditure, our investigations indicate that the programme is out of scale with the needs and we feel that it has no hope of even keeping pace with the large increase in the number of vehicles which we have noted." The present programme of road building should not be delayed awaiting further studies of the national needs, the Board asserts; it considers that road conditions are so menacing that holding up improvements would only make matters worse. "The effect of any greater use of scientific methods" the Board's report continues "should develop and be felt increasingly while construction proceeds. Moreover, the present schemes will provide a unique opportunity to determine by means of surveys and 'before and after' studies the ways in which new roads and other road improvements facilitate the flow of traffic and reduce accidents. In our opinion it is vital that this opportunity should be used to the fullest degree."

There could hardly be a better-informed, more authoritative opinion than that of the Road Research Board. No further comment is necessary to demonstrate the false economy of procrastinating over a major road programme. But this extravagance by parsimony is not confined solely to the roads themselves. It is felt in the running of the Laboratory as well. Allocations of staff have been unsatisfactory and work has had to be suspended on some researches because there were no funds to buy the equipment for it. "It seems to us," the Board says, "unrealistic that work of such importance to the nation at the present time should be handicapped in this way by a shortage amounting only to a few thousand pounds." Yet another consequence of the fossilisation of British roads is brought out. The training of traffic engineers, also, has been neglected, the report points out, and this country is seriously behind others in these matters. Clearly a drastic change in the official attitude to the nation's road problems is long overdue.

A Seven Day Journal

Anglo-German Atomic Energy Agreement

AN agreement made in London last week, between Her Majesty's Government and the Government of the Federal Republic of Germany, provides for co-operation on the peaceful uses of atomic energy. Under this agreement, the Federal Republic of Germany may obtain, on terms to be settled, research reactors and the necessary fuel elements, and unclassified information on topics (to be decided) concerning the design, construction and operation of these reactors. The Atomic Energy Authority will, wherever possible, provide facilities for training, and the parties to this agreement will help each other to obtain the research quantities of materials needed for their atomic energy programmes. In addition, the Germans will probably purchase from British industry a research reactor of the "swimming pool" type and a high-flux research reactor for testing materials, similar to the "Pluto" reactor under construction at Harwell. It is stipulated that reactors, materials and information supplied under the agreement will be used for peaceful purposes only, and provision has been made for safeguards to ensure this. The parties to the agreement recall their intention to support the International Atomic Energy Agency. When the Agency has been set up they will consult with each other about the possible application of Agency controls in respect of the present agreement. The agreement is for ten years and may be renewed for further periods, if the parties to it so desire.

Tonnage Oxygen Plant Opened at Margam

A NEW tonnage oxygen plant, built at Margam, near Swansea, by the British Oxygen Company, Ltd., was inaugurated on Wednesday, August 1st, by the Home Secretary and Minister for Welsh Affairs, Major Gwilym Lloyd George. The actual inauguration ceremony was rather unusual in that the plant was linked by television to the board room of the London office of the British Oxygen Company, Ltd., where the Minister started the plant by remote control whilst the audience watched the plant at Margam on television screens. After the starting ceremony a "tour" of the works was made by television. This plant, the first of its kind in Great Britain, has a capacity of 100 tons of oxygen a day and its output is supplied by pipeline to the nearby works of the Steel Company of Wales. A second plant of 200 tons per day capacity is now under construction at Margam, and the British Oxygen Company, Ltd., is also building plants of 200 tons per day at Scunthorpe and Middlesbrough, and 100 tons per day capacity at Consett, Co. Durham, and Ebbw Vale, South Wales, to serve steelmaking firms. It should be mentioned that the word "tonnage" in connection with oxygen making plants of this kind is used as a matter of convenience to avoid the use of large numbers, 1 ton of oxygen being equivalent to some 26,000 cubic feet, and it does not in any way denote a particular type of the gas. In his address at the inauguration ceremony, Mr. J. S. Hutchison, chairman of the British Oxygen Company, Ltd., pointed out that the principles in regard to various applications of oxygen in steelmaking, and in regard to open-hearth practice in particular, had been known for some time. Developments of these principles for their application to British practice had, he said, been achieved by individual steel companies, the British Iron and Steel Research Association and the British Oxygen Company, Ltd., working freely in conjunction with one another. As a result of these developments in open hearth and Bessemer practice, the tonnage use of oxygen had become perhaps the most decisive technical development seen in British steelmaking since the war. In practical trials with certain of the steel companies, Mr. Hutchison's firm had demonstrated increases in output of 15 and 25 per cent for different processes. In a typical case, he stated, an annual output of steel of, say, 100 tons could be increased to 110 tons by the employment of 1 ton of oxygen at a capital cost of £10. This compared with the £100 that would be required to get the same increase in output by extension of open-hearth capacity in the traditional way. The new plants also had a wide degree of flexibility in the amounts of gaseous oxygen and liquid oxygen which could be produced, as gas not immediately required could be turned into liquid oxygen for other purposes. Further, stated Mr. Hutchison, there was another technical advantage in that high purity oxygen was made in tonnage plants, which was beneficial in certain steelworks applications and suited all processes.

The Engineer
100 Years Ago
(AUGUST 8, 1856)

"INSTITUTION OF CIVIL ENGINEERS"

"It is with some satisfaction that we direct the attention of our readers to the issue from the press of two parts of the Minutes of Proceedings of the Institution of Civil Engineers. These parts form the latter half of the fourteenth and the first half of the fifteenth volumes, including the proceedings to the 12th of February of the present year. This shows a very marked improvement upon the rate at which the papers have been hitherto published; and although we are aware that complaints have been loud and numerous from several quarters as to delay in publishing, yet we may we think take some credit to ourselves for having brought about so favourable a change, having felt it a duty some time since to make some severe comments on the system of delaying the printing of the papers until almost all interest attached to them had passed away.

"We remarked, at the time, the favourable position in which the sister Institution at Birmingham stood with regard to the promptness of the publication of its papers, and expressed a hope that so worthy an example as was shown in that case would be followed. We, therefore, accept the present issue as a good earnest of future intentions, and for ourselves and the members of our profession generally, we thank the retiring secretary, Mr. Manby, for the evident care and labour he has bestowed in editing the parts now before us. We must also congratulate him on having so boldly disarmed those speakers at the last general meeting, who made such loud complaints on the subject of the payment for extra assistance in editing the former Minutes of Proceedings. The contents of the present parts show clearly that, as yet, the institution has nothing to fear on the subject of procuring good and useful communications, and although the delay in publication, we know, has operated very prejudicially in this respect hitherto, we may now hope soon to see the names of some of the more experienced members of the profession amongst the contributors."

Institute of Physics

THE annual general meeting of the Institute of Physics was held in London recently. The annual report of its board records that during 1955 the membership of the Institute passed the 5000 mark, and that 726 applications for election or transfer were considered, compared with 579 in the preceding year. The Institute's recently established graduate examination was taken in four centres by fifty-four candidates, but only eleven of them satisfied the examiners. The report says that the board has continued to comment upon and support proposals for the development of facilities for higher technical education. On the invitation of the Ministry of Education it nominated a member to one of the two boards of studies set up to advise the National Council for Diplomas in Technology. The report says also that, concerned at the increasing evidence of declining numbers of advanced students in the physics departments of several well-equipped technical colleges, the board decided to institute an inquiry into the availability of places for physics students in the universities and larger technical colleges in this country. At the annual meeting, Mr. O. W. Humphreys, director of the research laboratories of The General Electric Company, Ltd., was elected president of the Institute; Dr. B. P. Dudding was elected a vice-president; Dr. J. Taylor, honorary treasurer, and Professor F. A. Vick, honorary secretary. Sir George Paget Thomson was elected to honorary fellowship of the Institute, in recognition of his contributions to physics and his services to physicists.

Speed with Safety

THE Engineers' Guild recently drew attention to the fact that the Minister of Transport has yet to appoint, or define the qualifications and powers of, the Road Accident Investigation Officers to whom he referred last autumn. In March, 1953, the Guild submitted detailed proposals to the Minister for an organisation by which qualified engineers in each county would report, ultimately, to a Road Accident Inspectorate under the chief engineer of the Ministry of Transport. The specialist reports made available would allow what money was available for road improvements to be spent effectively, and would also provide factual information about the mechanical performance of vehicles and their equipment. The essence of the scheme is that it be operated, and public inquiries conducted, by engineers competent to assess the defects in highways and the method and cost of rectifying them. The recent history of road transport in this country has shown that it is costing more than £150 million per annum in accidents, and a study of the causes is clearly called for. In this country, the Guild observes, further restrictions on traffic would be extremely costly, and the object must be to save the time of industry and the individual. The Guild, therefore, concludes that the time has come to institute a trial of its scheme in one county for a year at least.

Cut-offs in Modern Hydraulic Diversion Works on Alluvial Rivers

By S. LELIAVSKY, Ph.D., M.I.C.E., M.Am.Soc.C.E.

No. I

Though forever concealed below ground, the under structure of a hydraulic work, e.g. barrage, weir, lock, &c., is frequently more important—and might be more difficult to build—than the superstructure which appears above ground., The under-structure may again be divided into two main constituent parts : the more or less horizontal floor and the vertical cut-offs placed beneath it, to render it more efficacious in counteracting the dangerous effects of enforced percolation. The construction methods employed in building the floor are those commonly used in other works, but the cut-offs are a sui generis *case, which is described in this article.*

Statistical Examination

FROM the standpoint of the elementary theory of Bligh, a flat apron would supply, were it made long enough, a suitable type of foundation for any barrage built on a granular, permeable soil. More advanced theory as well as practical experience tend, however, to show that this conclusion is basically erroneous ; in fact, a flat apron is an extreme assumption, as objectionable in practice as the diametrically opposed extreme, viz., a single row of sheet piling. In one case we have horizontal creep alone ; in the other there is vertical creep only. Except in temporary works, we must have both creeps (vertical and horizontal) combined together, and their relative importance is one of the main problems of up-to-date hydraulic engineering.

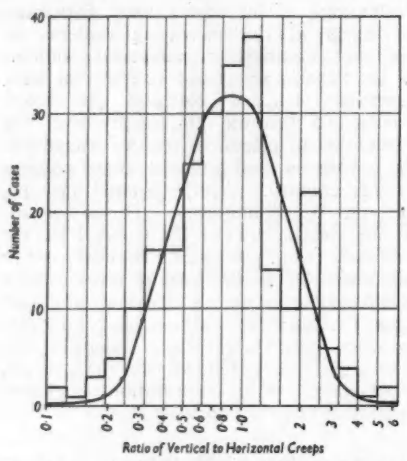


Fig. 1—Frequency curve for Professor Lane's table

One of the best known studies on the subject is Professor Lane's table containing over 250 entries, yielding the ratios of the two types of creep in existing dams (see "Security from Under-Seepage," *Trans. Am. Soc. C.E.*, No. 100, 1935, page 1235, *et seq.*).

An attempt to examine Professor Lane's table statistically is shown in Fig. 1.

This diagram represents the usual Gaussian frequency curve, with the only difference that instead of the ratio itself (i.e. $K=V/H$, in which K is the coefficient, while V and H are the lengths of vertical and horizontal creeps*) the abscissæ in the diagram are the logs of these ratios.

To the designer east of the Atlantic the diagram may possibly come as a surprise, for it gives as average ratio the value about unity. Such a high average is, however, the result of the fact that by far the greater majority of the dams listed in Professor Lane's table are American and that the American design depends to a much greater extent on vertical obstruction to seepage flow, rather than on long, flat aprons, as is the case in Egypt, India and partly on the European Continent.

It would possibly be wrong to say that the popularity of the long-apron alternative in these countries is due to the influence of Bligh's theory. The truth seems to be that Bligh has expressed in his theory what had been a general tendency, i.e. an inner feeling, derived from vast experience with Eastern barrages and dams.

To reconcile the two extreme postulates seems, so far, impossible. We may only record the fact that whilst the American method chiefly depends on seepage control methods, such as weep holes, drain wells, drain trenches, &c., in combination with various types of "constructed" or "injected" cut-offs, the opposite "Eastern" tendency is to consider these various devices as "a second line of defence" only, whilst the main factor of safety is supposed to depend on a combination of a wide apron, with enough vertical obstruction to render the latter fully effective. For instance, in Egypt, in capital works the average ratio of the two types of creeps averages about one to four.

* In the case of inclined creep, slopes steeper than 45 deg. are added to V, whilst flatter slopes are included in the calculation of H.

Two Basic Types

Turning now to the cut-offs themselves, it will be observed, in the first instance, that there are two basic types thereof :

(*a*) Thin partitions, i.e. sheet pilings of various types and description, whether in timber, steel, or concrete, or a combination of these materials.

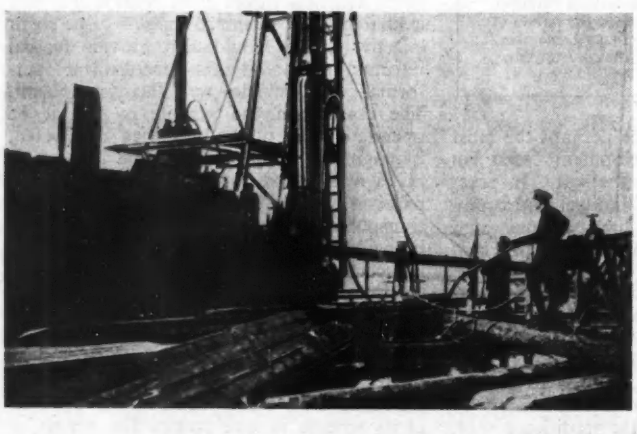
(*b*) Thick walls, including the Indian type of bottomless well, sunk in such a way as to form a continuous curtain wall, and the Egyptian type of cut-off, made of two parallel lines of sheet piling, driven 3ft to 6ft apart, with concrete filling in between them, cast under water.

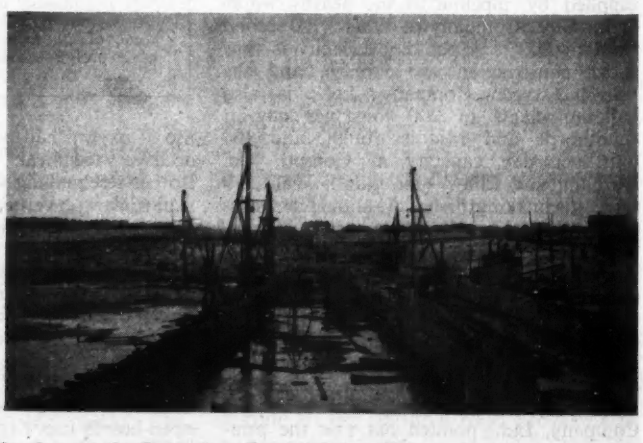
Hydromechanically, the difference between these two general types resides in the extreme vulnerability of the former, as opposed to the capital safety of the latter.

According to advanced modern views, this difference is not only a question of a greater structural safety coefficient, incorporated in a thick wall as compared with a thin partition, but originates in the cumulative effect of the frictional resistances, preventing a particle of soil from being carried by the percolating water through a gap or crack in a thick wall. This frictional effect, sometimes assimilated to "arching," depends obviously on the ratio which the length of the channel bears to its width. In a thin curtain, such as that of a web in steel sheet piling, this ratio is for all practical intents and purposes nil. This explains why it is that relatively narrow holes (such as those due to imperfect pile-driving) are known to have brought about the collapse by piping of entire barrages.

Quite different, however, is the case in a "thick wall." Though the fact may be little known, the wells of the imposing heavy cut-offs of some of the Indian weirs, appearing in Bligh's book as illustrations of his theory, were actually sunk with gaps several inches wide between them ; and this did not seem to have caused much trouble. Quoting from Morley Parker's book† : "The Indian well-sinkers are very skilful, and probably water-tightness is eventually secured through the stanching by silt that

† *The Control of Water*, page 690.





Figs. 2 and 3—(Left) Driving timber piling (Right) Konstantinovsky dam on the Don : three lines of timber piling can be seen

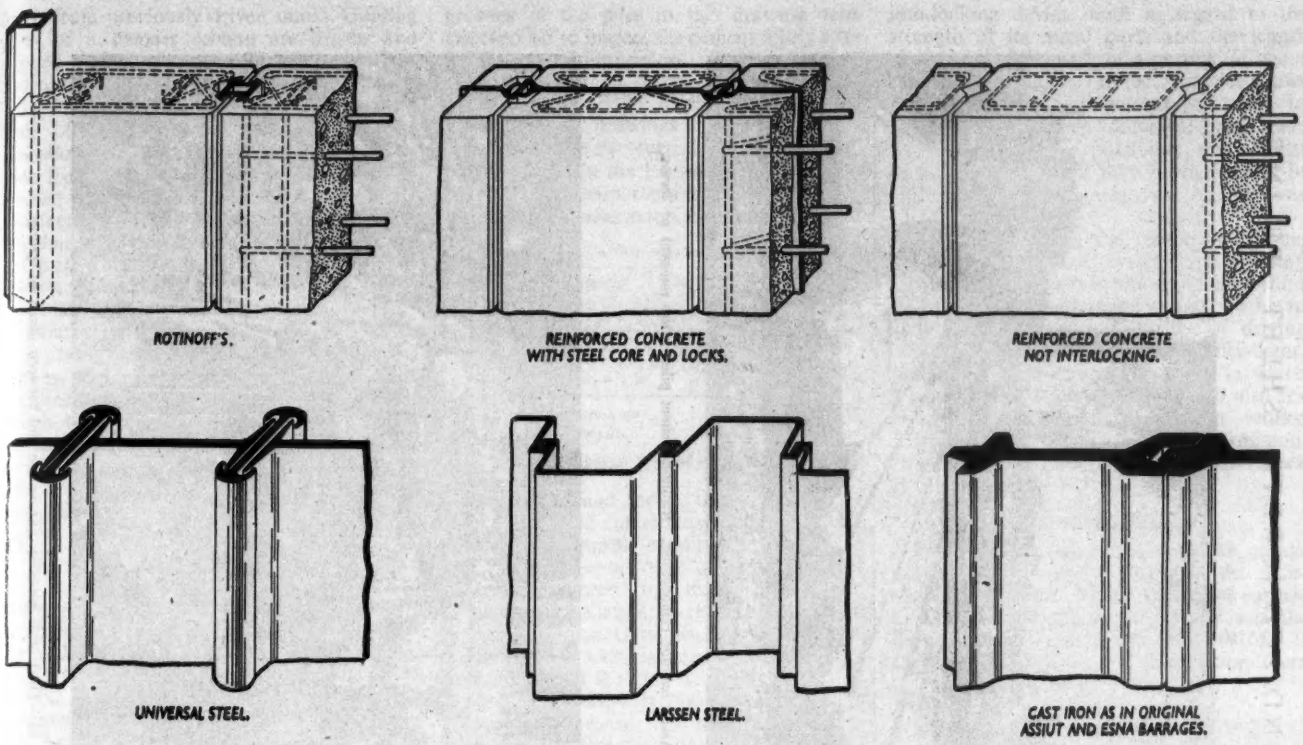

ROTINOFF'S.
REINFORCED CONCRETE WITH STEEL CORE AND LOCKS.
REINFORCED CONCRETE NOT INTERLOCKING.
UNIVERSAL STEEL.
LARSSEN STEEL.
CAST IRON AS IN ORIGINAL ASSIUT AND ESNA BARRAGES.

Fig. 4—Various types of cut-offs frequently used in barrages

occurs as the weir grows older. In one case, where such a line of wells was momentarily exposed, the interstices appeared to be filled with a material resembling good puddle." Though this author thinks that Egyptian sand being much finer must be less effective as a stanching medium, it was nevertheless found during an experiment

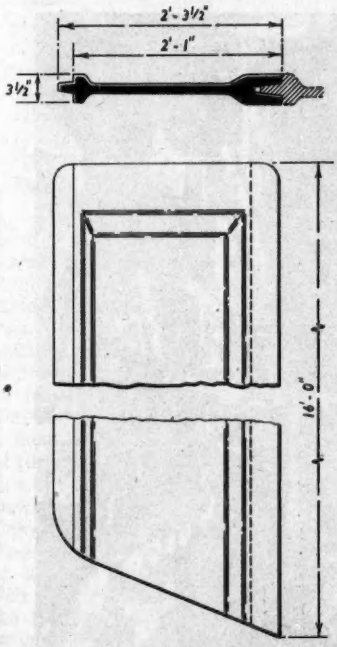


Fig. 5—Detail of cast iron pile

with such sand carried out at Giza, that the filling of the trough through which water had been percolating during several weeks became as hard as brickwork and had to be hammered out of the cast iron trough after the experiment was completed.‡

Of course, with the knowledge we now possess of the importance and danger of percolation, no one would think of deliberately leaving inches wide gaps in a presumably watertight curtain wall without at least attempting to fill in these gaps by some means or other; in fact, according to Khosla, Bligh put sheet piles to close the gaps in between the wells of the Narora Weir (although no reference to these sheet piles appears in the pages of his book) when the latter was remodelled; the same procedure was also adopted in some early Egyptian works (Ismailia Regulator and others, 1888–1889). Still the fact remains that lack of watertightness in a thin partition is far more dangerous than a gap or crack in a thick wall, be it a vertical cut-off or a horizontal 3m deep masonry or concrete floor, similar to those incorporated in the Egyptian type of barrages. That is a point to be borne in mind in assessing the merits of thin reinforced concrete aprons, as compared with the traditional heavy type. Sheet piling must therefore be driven with considerably greater care than is called for in executing thick curtain walls.

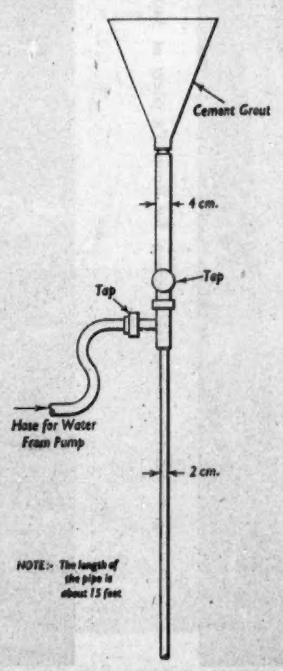


Fig. 6—Grouting pipe for cast iron piles

Timber Piling

From the historical standpoint the first, parent type of all sheet piles is, of course, the timber piling, which has been extensively used in the past and is still frequently employed

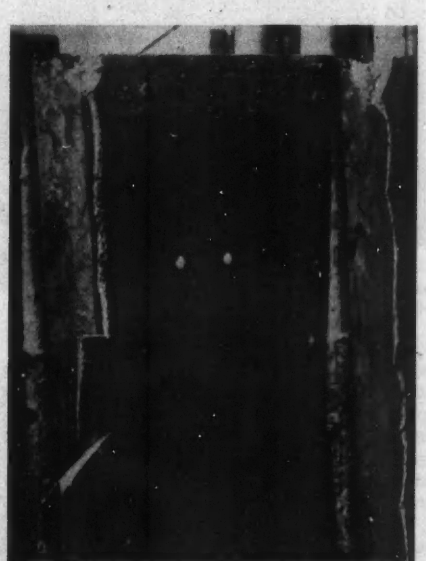


Fig. 7—Cast iron piling uncovered during remodelling of Esna barrage

at present in countries where wood is relatively cheap. More than for any other type, its success depends on the excellence of execution and careful supervision of the work whilst being carried out. As shown in Fig. 2, three timbers are frequently bolted together before being driven. All measures are then taken to prevent such a unit separating, below ground

‡ The curious point about it was that this sand filling still remained fully pervious.

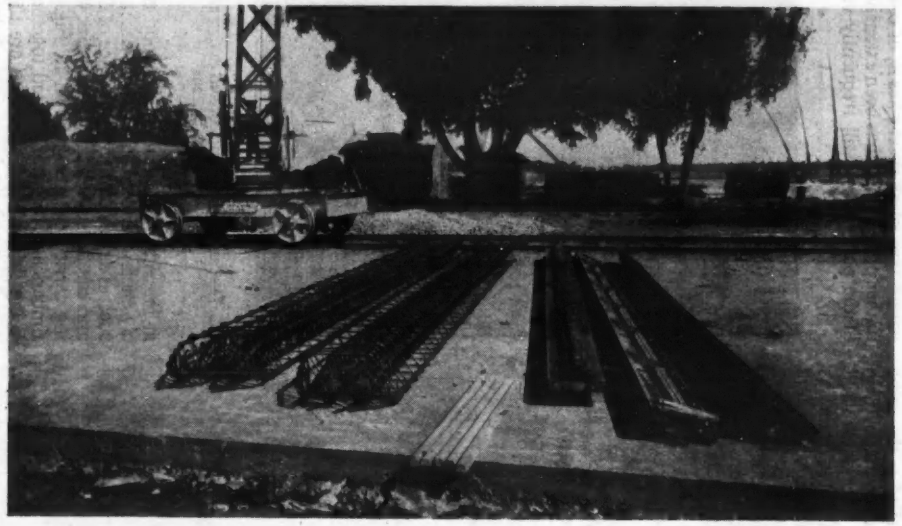


Fig. 8—Steel forms and reinforcement for Rotinoff's piling at Assiut barrage

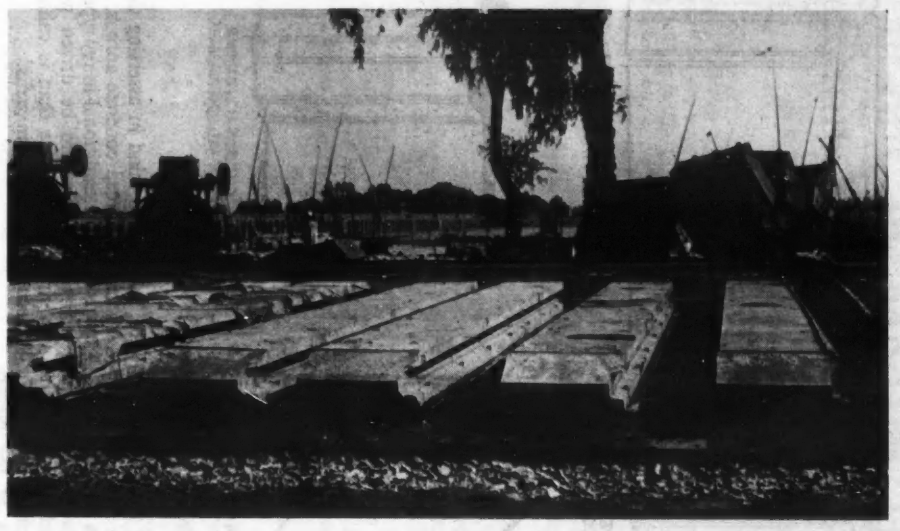


Fig. 9—Assiut barrage remodelling. Rotinoff's sheet piles after removal of forms

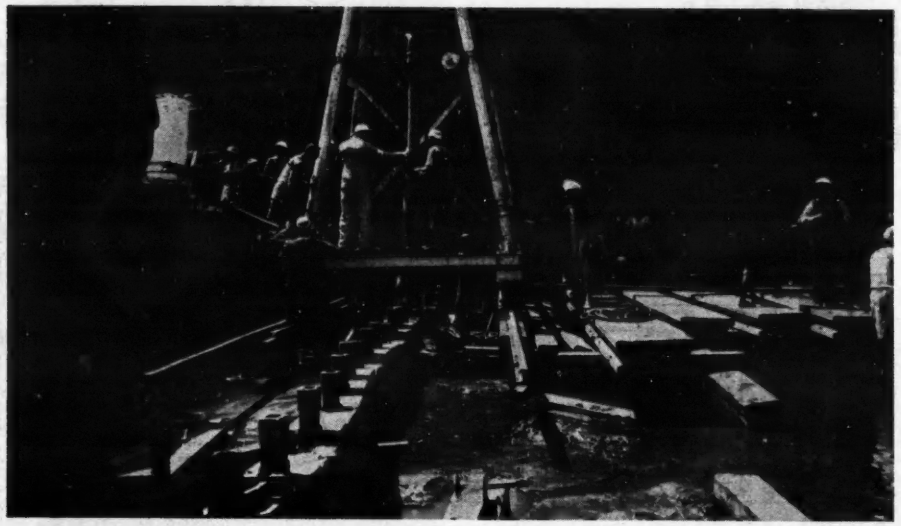


Fig. 10—Rotinoff's sheet piling being driven at Assiut barrage

Fig. 11—Thick wall cut-off : excavating soil between lines of piling

level, from previously driven units. Guiding piles of a heavier section are driven and capped before the cut-off piling itself is attempted.

In Fig. 3 there are illustrated three main lines of timber pilings driven under the Konstantinovsky dam on the Don. It is seen from this picture that the execution of timber cut-offs can be done completely satisfactorily. This depends chiefly upon whether trained staff is available.

On the other hand, some among the well-known failures of irrigation works, such, for instance, as that of the old Menufia Regulator in Egypt (1910), are alleged to have been due to defects in the timber pilings. In fact, from the inspection of the remains of the timber piling of this regulator, which were washed out by the rush of the water during its failure, it seemed that the execution was not to the required standard, which naturally discouraged engineers from using timber piles again in other works, in Egypt.

Cast Iron Piling

Fig. 4 shows the six main types of non-timber pilings, most frequently adopted at present for making cut-offs under barrages and weirs. The drawing in the right-hand bottom corner of the diagram shows the cast iron piling invented by Sir Benjamin Baker and used in the Assiut, Zifta and Esna Barrages on the

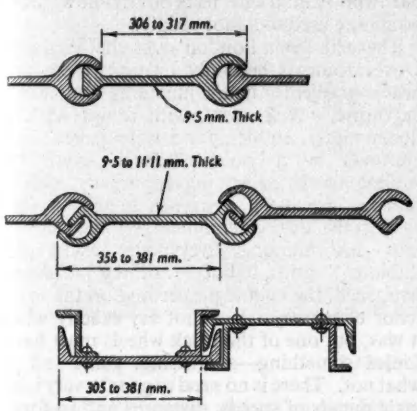


Fig. 12—Details of interlocking piles

Nile. Though a certain amount of apprehension existed at one time as to the watertightness of the curtain obtained in this manner—for the arrangement is not, strictly speaking, interlocking—these fears were shown to have been groundless when parts of such pilings were uncovered during the remodelling works on the barrages.§ The chief reason for using this type of pile in preference to any other was that cast iron was then believed to resist rust better than steel (or even wrought iron). The details of such a pile are given in Fig. 5. The tongue is somewhat shorter than the groove, in order to leave a clearance for cement grout injections. These were carried out as follows: after a certain number of piles had been driven the pipe shown in Fig. 6 was lowered down into clearance by jetting, and thereafter cement grout was let in whilst the pipe was gradually withdrawn. Careful inspection of all old pilings which had to be broken down during the remodelling of Esna Barrage (1944–1946) did not reveal a single fault in the grouted joint. For instance, in the broken line of old cast iron piling, which is shown in Fig. 7, all the joints are seen to be completely filled with hardened cement. The grooves of the piles in this drawing were knocked off to inspect the cement filling after forty years of immersion.

§ During the remodelling works of Assiut Barrage the old cast-iron sheet piling was found (over a certain length of the apron) to have separated from the concrete, but this is another story altogether, which in no way reflects on the adequacy of the piling as such.

Steel Piles

The next two drawings in the lower row in Fig. 4 represent two typical sections of rolled steel piling. In the Larssen type, shown in the middle diagram, there is only one section, which is used alternately on its convex and

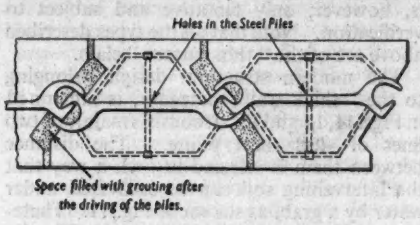


Fig. 13—Another type of concrete piling

concave sides and forms, in this manner, a strong and rigid curtain, capable of resisting a not inconsiderable bending moment. The figure is representative of a large variety of designs produced by many well-known firms, such as Krupp, Terre Rouge, Dorman Long, Bethlehem, Carnegie, and many others. The left hand drawing in the same row shows the arrangement of the Universal piling which is typical of a somewhat different idea, for in this case we have two, and not only one, profiles. From these two, one, the clutch, is a special section, manufactured for pile driving purposes, whilst the other is an ordinary steel joist, such as used in bridges, floorings, &c. There is much difference of opinion as to which of these two typical designs, i.e. the Larssen or the Universal, is preferable. The choice depends, of course, upon the criterion used for comparing their relative merits.

Some designers maintain that the minimum thickness of the metal as opposed to the weight of the steel per unit of surface (i.e. the mean thickness) is the true criterion, for on it depends the percentage of exposed area, and hence, the rust-resisting capacity of the curtain. Others believe that the second moment of the section is the more important factor, for it determines the resistance of the piling against bending.

From both these standpoints the principle of the Larssen type is preferable, but there is another point also, which has to be taken into account; namely, the efficacy of the interlocking device, both in regard to the strength of its metal parts and the length and shape of the path of a particle of water travelling through it. In fact, practice shows that in spite of all precautions taken to prevent gaps between individual piles, there is always a remote possibility that, whilst driving, the interlock may be damaged. In this respect the Universal type has obvious advantages.

This is, therefore, the reason why some designers prefer the Universal type of piling for permanent work in the more important cut-offs, while the Larssen group, owing to its greater rigidity and facility of driving (and pulling out) is used for coffer-dams, sudds and other temporary works in which it can be reused several times, and also for secondary cut-offs in permanent works. This, however, is a matter of opinion. Other forms of interlocking piles are shown in Fig. 12.

Concrete Piling

From among the three concrete pilings shown in the top row of Fig. 4 the right-hand design is the oldest. One of its earliest applications known to the author was the Kotchetovsky dam on the Don (1916). It seems to have given full satisfaction there

Fig. 15—Thick wall cut-off: filling the space between sheet piles with concrete to form cut-off at Edfina barrage

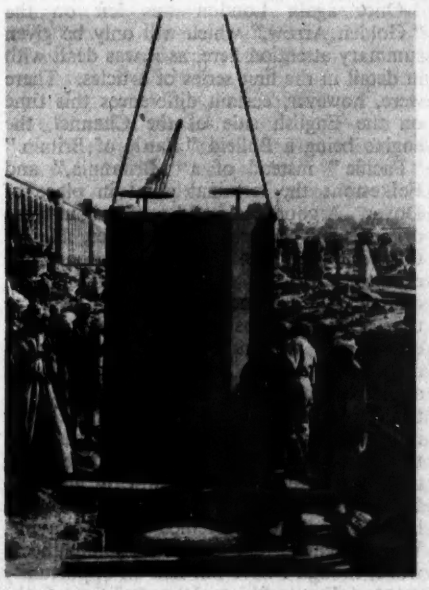


Fig. 14—Thick wall cut-off: inserting partitions

but this may be a matter partly of highly-trained staff being available and partly of luck, for there is no guarantee that the heavy piles are driven in close contact throughout their full height and that the two sides of the rhomb-shaped space, provided for cement injections, are in line with each other below ground.

For these reasons the type is more popular with harbour engineers, who use it in the construction of quay walls, wharves, &c., where watertightness of joint is not essential —rather than with dam builders whose object it is to cut seepage trajectories.

This explains why suggestions for using this type of piling for the cut-offs of Esna barrage, made by some of the tenderers for the remodelling works, were not accepted. A design similar to that shown in the middle diagram in the same row was then worked out instead, in the author's office, but altered

on his suggestion at the eleventh hour for another design.

From all the concrete pilings the one at the left-hand top corner of the diagram is among the most suitable for making watertight cut-offs. It is a patented type (Rotinoff's) which was used in the remodelling works of Assiut barrage. Better to explain the method of work attention is called to Figs. 8, 9 and 10, which show, respectively, the steel reinforcement and the piles as cast and as driven. The main advantage of the system is that the clutch, which is withdrawn after the driving and injecting are completed, keeps the adjacent piles in contact during the driving operation and ensures, in this manner, a continuous curtain wall. The space between the piles is first washed out by a jet pipe and then liquid cement is poured into it, whilst the clutch is withdrawn. Another type is shown in Fig. 13.

There was another debatable point in connection with all the concrete pilings which attracted a certain amount of attention whilst the Assiut works were in progress; namely, that none of these piles can be driven into sandy soil, as is the case with steel piles, but must always be jetted down. In fact no hammer whatever was used at Assiut barrage for driving the concrete piles, which went down easily under their own weight, provided jetting was effective. The question then arose as to whether the soil which had been thus disturbed would possess the same d'Arcy's coefficient, after it had settled down again. Experiments on the subject might be of interest. If experience with concrete bearing piles, jetted down in sand, can be interpreted as a significant analogy, it would seem that the process causes the sand to be even more compact, after a lapse of a certain time period (twenty-four to seventy-two hours). This conclusion is, however, only tentative and subject to verification. Note that all the types described above are of the "thin curtain" class.

The modern structural design belonging to the "thick wall" category, is illustrated in Figs. 11, 14 and 15. It consists mainly of two lines of steel sheet piling. The distance between them is selected in such a way that the intervening soil can be excavated under water by a grab, as shown in Fig. 11. Thereafter this space is divided into sections by partitions (see Fig. 14) and filled with concrete under water (see Fig. 15). This design has been used on four Egyptian barrages and apart from acting as a cut-off, works also as a bearing foundation. It must, however, not be used too close to existing work (about 20m minimum distance), because it has been observed that whilst the soil in between the two lines of piling is being removed, the encircling ground surface settles, say, within a radius of twenty metres. This settlement is usually attributed to the suction effect.

(To be continued)

Further French Locomotive Experiences

By EDWARD H. LIVESAY

No. I—LONDON-PARIS, VIA FOLKESTONE AND CALAIS: BULLEID AND CHAPELON "PACIFICS"

A SERIES of articles describing experiences with locomotives of the S.N.C.F. was published in THE ENGINEER two years ago. They covered quite a wide field, but several routes and interesting engines had to be left out of the programme due to lack of time; in the northern and north-eastern regions especially this was the case, where fine work was being done by unique machines, express and freight. The blanks were filled in recently during a return visit to France, when I made the acquaintance of several classes of engine worthy of consideration before the rising tide of electrification engulfs them. I found very creditable work being done by both old and rebuilt machines, especially the latter; performances all the more striking because, as was pointed out in a preceding article dealing with Monsieur André Chapelon and his contributions to locomotive efficiency, it is in just such engines that the correctness of his theories has been so clearly vindicated. During some of these northern runs it was often hard to realise that the engines might be thirty or forty years old, so completely had they been rejuvenated by reconstruction in accordance with Monsieur Chapelon's conceptions, so greatly had their power been increased. Nothing could show more plainly the value of modernisation as applied to engines which, while basically of sound design, and originally adequate, were no longer able to meet later demands. These machines, outmoded, or soon to become so, had been given a fresh lease of life by rebuilding, and their original capacity greatly increased by the incorporation of structurally minor but potentially major improvements. The Havre and Cherbourg runs were specially interesting in this respect, as the services over these routes were handled by such rebuilt engines; the trains were heavy and fast, and the Cherbourg line was particularly trying from a gradient point of view; it seemed to me more severe than any I had ridden over in France, the profile being really impressive.

Once again London was left on the "Golden Arrow," which will only be given summary attention here, as it was dealt with in detail in the first series of articles. There were, however, certain differences this time on the English side of the Channel, the engine being a Bulleid "Battle of Britain" "Pacific" instead of a "Britannia," and Folkestone the terminal point in place of Dover. A good deal can be said about these original and controversial engines, but as this would be somewhat outside the scope of these articles I will content myself with one or two comments, while at the same time expressing considerable regard for them, despite the fact, admitted by people concerned with them, that certain features adopted with good intentions have not turned out quite all their talented designer intended. Personally, I am well disposed toward them for several reasons, one being that they attested a praiseworthy effort to break out of the rut into which British locomotive practice seemed to be straying. When extended they certainly do magnificent work, though I have not had an opportunity yet to observe it at close quarters; the "Golden Arrow," for example, does not call for very strenuous effort on the part of either engine or observer; for that, one must wait until south of Calais.

The "Golden Arrow" left Victoria punctually at 1 p.m., in fine weather, headed by "Battle of Britain" No. 34,071, "601 Squadron," in charge of enginemen Allman and Everson, of Stewart's Lane, with Inspector Knight as supercargo. The load was roughly 400 tons, and though the getaway from Victoria is almost immediately complicated by a 1 in 62 rise to Grosvenor Bridge, there was no slipping, the regulator being tactfully handled in the way these "Pacifics" demand. Their cabs are well-arranged, though somewhat cramped, due to the restricted loading gauge of the S.E. area. The thermic siphon, removed from some of these engines, was still in position on this one, but the pressure had been reduced from the original 280 lb to 250 lb. The steam-operated gear of the butterfly firedoor was missing, only the long hand lever remaining; on asking Everson why it had been taken off he said something to the effect that he was just as happy without it, but the exact reason for this escapes me; prejudice due to insufficient experience of the foot treadle arrangement very likely accounts for his attitude. The usual kind of hand-operated firedoor strikes me much as a hand clutch would on a car, a device common enough in the old days, but who would go back to it now after becoming used to a foot pedal?

The exit from London over the Victoria/Dover route is certainly trying; there are heavy gradients, many junctions and much curvature. Well away, with things settling down nicely, suddenly we were jarred into alertness by a violent wrench from the trailing truck, coinciding apparently with a scissors crossing; a wrench severe enough to flash the idea of derailment—of the truck—into my mind. Everybody exchanged dubious grins, but nothing further happened, the engine proceeding on the even tenor of its way. I cannot say exactly what it was, but one of the truck wheels must have fouled something—a crossing, guide rail or what not. There is no need to go into very intimate details of speeds, distances and so forth on this run; a maximum of 80 m.p.h. was reached on the long 4-mile drop from Sevenoaks tunnel down through Hildenborough; Tonbridge, where there is a severe service slack, was passed at 1.45, the last 8 miles having been covered in 8 min. The engine's riding at speed was good, but quite different from the "Britannias"—light, springy, more like that of French engines. The action of the trailing truck on these engines always seems to me good. No. 34,071 was steaming well under all conditions, Everson's firing being of the little-and-often kind, which one does not always see nowadays. I wondered why the pressure had been cut 30 lb, the original 280 lb giving a very useful power reserve, one would think. The controls on these engines are well arranged, and the convenience of the crew has been properly considered; the reverse gear is steam operated, and the fluorescent figures on the dials are a thoughtful provision. Both injectors are on the fireman's side, which as a rule is the best place for them; electric light is another good feature, though it has not always been in working order in my experience. I had good reason to notice that the top of the window is too low for a tallish man in the fireman's seat riding with his head outside, which is preferable where a deflector strip is provided. One's position is perforce humped and uncomfortable, and one's skull is brought into sharp contact with

the frame at every lurch, which is both undignified and painful. Everson found it amusing—when it was my head. This little vexation arises from the restricted loading gauge, particularly affecting the Tonbridge line on which we were running, as it brings the cab cornice rather low down.

These engines are quieter in action than the run of ordinary types; one notices this in the cab. The valve gear is all enclosed, chain driven, working in an oil bath, force lubricated, and as there is no outside crank drive, no disturbing factors can arise from it, and its operation is quiet. All the motion is light, the cylinders being only 16¾in by 24in, the latter dimension being probably chosen to reduce piston speed resulting from 74in wheels. The reciprocating weights are unbalanced, which reduces hammer blow to a minimum ; when one of these engines is in bad shape—I have ridden once on such—it is less objectionable than a more orthodox machine, and easier on itself and the track. No matter how "run down" a Bulleid "Pacific" may get, I do not think it would become such a knocking, pounding wreck as a certain 4-6-0 I rode last year out of London, double heading a well-known train to the North. It was in such deplorable shape that I wondered why it had been allowed to run at all, let alone on a fast train ; it was so bad that I had not the heart to draw attention to it subsequently when an official inquired how I had enjoyed the trip ! In common consideration for him and other officials, silence was best. But the enginemen had plenty to say about it, such as : "This is the kind of thing that takes the pleasure out of railroading nowadays." Before the war I am sure an engine in such condition would never have been allowed out of the shed. I cannot imagine a Bulleid "Pacific" ever behaving like that.

I gave little attention to the position of the controls, and how they were being handled, the work not being strenuous enough to give much concern to either engine or crew, but I did note that the run again demonstrated the passing of the pre-war "full regulator and short cut-off" method of driving, which is no longer the fetish it once was. Not that it ever was on the Southern system—possibly because it originated on the Western ! During this run, on the rare occasions when the regulator approached the "full" position, the steam chest gauge gave readings very close to B.P., showing all was well with supply and front end design. Yet apparently the above-mentioned theory still has its advocates. Describing in THE ENGINEER the performance of an engine taking a famous train up a long and fairly stiff gradient out of London, I mentioned that the regulator was about three-quarters open, and the cut-off I forget just what, but evidently not what the divisional superintendent thought it should have been, because he had the accompanying inspector on the carpet, to find out why he had allowed the driver to handle his engine in this theoretically inefficient manner. It surprised me to hear of this incident, as surely the superintendent must have known that the old method of driving has pretty well been discarded nowadays. I am safe in mentioning this little gaffe, as Inspector Hart has always held me guiltless, and the superintendent, alas, has since died. But it just shows how an observer can quite unintentionally get somebody into trouble merely by being factual.

"Fleche d'Or," S.N.C.F.

Other useful fittings noticed were window wipers, with water-spray attachment, necessary on a locomotive where soot may foul a window and cause more difficulty than rain. Without a water spray, the glass is apt to be smeared by a wiper, making conditions worse than before. Rocking and drop grates are found on these engines. I suppose they are essential nowadays when coal is apt to be so bad. The "look-ahead" is rather restricted, but this is unavoidable, the overall width of the cab being only 8ft 7in, and nothing can be done about it.

Ashford was passed at speed, 2.10 ; 26½ miles in 25 min, including a permanent way slack to 15 between Marden and Staplehurst. The "Golden Arrow" came to a stand at Folkestone Junction at 2.25, 1 min early, and here the engine came off, its place being taken by another at the other end of the train for the 1 in 30 drop down into the Harbour Station. The final arrival time was 2.38, the 72 miles from Victoria having taken 98 min, but it is only fair to base the average speed on the time to Folkestone Junction, 50·1 m.p.h. Not very impressive, perhaps, but the distance from London is short and the first part of the route so unsuitable for high speed that it would scarcely be worth while, even if feasible, to attempt anything better, and the time saved would be negligible.

I crossed in a French ship, and at Calais a pleasant English-speaking official came on board to escort me through the landing formalities to the engine, No. 231–E44, one of the later Chapelon "Pacifics," which was in a siding awaiting the train's arrival from Paris. I had no difficulty in making friends with the crew, Mecanicien Noutour and Chauffeur Dess, though my French was not much better than it had been two years before. They were friendly and hospitable, and I settled down happily enough, troubled with none of the semi-apprehension felt on the previous visit. This time I was not a stranger in a strange land—I knew the ropes —everything, engine included, was familiar ; moreover, I had been advised that an interpreter would again come with me in the cab to Paris, so I was at peace physically and mentally. The engine pulling round to the train, I was delighted to find my friends, Monsieur Leseigneur, Chief of Traction, Nord Division, and Inspector Fillon, waiting on the platform, just as had been the case two years before, the former to drive and the latter to act as interpreter and courier. In every respect history was repeating itself, and I was well content that it should be so.

The run to Paris will also be summarised, as it was described in detail in the previous series, and everything was much the same this time. "Fleche d'Or," loaded to about 500 tons, left Calais at 6.09 p.m., 7 min late, accelerating fast, Calais Town being passed at 40 m.p.h., restricted. The long Caffiers bank, mostly 1 in 125, was taken at speed, begun at 60 m.p.h., and the summit passed at 45/50. The cut-offs in h. and l.p. cylinders were 45 and 50 per cent respectively, with about ¼ regulator, the engine working compound as usual ; b.p. was 17 hpz., steam chests 15. Coming down the south side the speed was up to the 74½ limit ; Boulogne (restricted) was gone through at 6.45, and Etaples at 7.02, 5 min late, so 2 min had been picked up already. The engine was behaving perfectly, both as to riding and steaming, though it is scarcely necessary to say so ; occasionally the l.s. injector was put on to prevent blowing-off when the regulator was shut, or nearly so ; when open, of course, the A.C.F.I. feed pump took care of water supply. Abbeville 7.36, Amiens 7.57, only 3 min late, another 2 min, 4 min in all, having been recovered. Thence to Paris the speed limitation became 81 m.p.h., and automatic colour-light signals took care of us. Handled by an expert, with most speed variation done on the valves, cut-offs on the two sets of gear were kept fairly close together, with a tendency for the l.p. to be somewhat longer, the engine continuing its seemingly effortless high-speed rush to Paris. Incidentally, when the regulator is shut, a by-pass allows passage of a little steam to the l.p. cylinders, for cushioning, and to prevent ingress of vacuum-induced smokebox ash. The coal was small and dusty, scarcely the "good coal" that Monsieur Chapelon subsequently said French express engines were supplied with ! The cab naturally got rather dirty, and by this time most of its occupants were getting grubby, too. Dess was worst, with myself a good runner-up, but I look on this as part of the game.

Reaching the top of the long Survilliers climb from Creil, with all the hard work over, only the downhill swoop into Paris remained. The time lag had been more than regained, "Fleche d'Or" arriving in the Gare du Nord at 9.28 p.m., 2 min ahead of schedule, having covered the 186 miles from Calais non-stop in 199 min, 56·1 m.p.h. The

engine coming to a stand, everybody straightened their backs and relaxed, and I was congratulating all concerned—with Fillon's help—on the successful conclusion of an enjoyable run, when the atmosphere in the cab suddenly became electric, Fillon turning to me and exclaiming, "Monsieur Chapelon is here! Monsieur Chapelon has come to meet you!" A very unexpected pleasure, this, all the more appreciated on that account; getting down, this meeting with the talented engineer took place in surely the most appropriate surroundings possible—beside one of his own engines, which had brought in a famous train, after a flawless run, during which it had shown its power in the hands of a driver fully capable of bringing out its potentialities to the full. The meeting, coupled with renewed association with the S.N.C.F. and its courteous officials, clearly called for appropriate and reciprocal gestures, and "La Maison Blanche" being conveniently near, to this hostelry we adjourned—but it is unnecessary to say more on that point. This was France!

(To be continued)

Calculation of Backlash between Gear-Teeth

By W. A. TUPLIN, D.Sc., M.I.Mech.E.

A powerful deterrent to full use of the adaptability of the involute system in gear design is the tedious nature of the conventional calculation of backlash between full-depth teeth. The difficulty disappears when the backlash is determined by a "difference formula" as is normal mathematical practice for a "small difference."

THE backlash between a pair of meshing gears is perhaps the most easily measurable dimension associated with those of the teeth. Possibly for this reason the amount of backlash is often given far more importance than is really justified, but nevertheless it is essential to have a practical procedure for determining to what depth a standard cutter must be sunk into the gear blanks in order that a mating pair shall have a predetermined backlash with some tolerance. In the case of involute gears intended to work at what are sometimes called "non-standard" centre distances, calculation of caliper settings by conventional methods is so tedious that it may persuade a designer to avoid it by specifying the use of a non-standard cutter to match the required "non-standard" centre distance.

In the issue of THE ENGINEER for March 21, 1952, the writer described a simple method of calculating this backlash, and the object of this article is to add a refinement, necessary because the original method, while satisfactory for gears of normal proportions, may not meet every requirement in extreme cases.

In the following, "normal backlash" is the minimum distance (measured, for example, by a feeler gauge) between mating tooth flanks of spur or helical gears cut to exactly standard depth, mounted at the designed centre distance and rotated as far as possible in a common direction so as to give maximum separation to the flanks concerned. In helical gears the normal backlash may be considerably smaller than backlash measured along the circumference of the meshing circle.

Normal backlash may be measured at any distance from the axis of the gear. At every point it is equal to the backlash measured at the base cylinder of either gear in a direction perpendicular to the base helix.

The blank diameter of a helical gear with t teeth cut by a British Standard generating cutter of normal pitch p_n in such a way as to have axial pitch p_n cosec σ is

$$d_b=\frac{p_n}{\pi}(t\sec\sigma+S_p)$$

where σ is the helix angle at the reference cylinder (where the normal pitch is p_n) and S_p is a positive number that may have any value within a defined range, e.g. less than $4-\frac{10}{t}\cos^3\sigma$ and greater than $4-\frac{t}{10\cos^3\sigma}$.

Similarly the blank diameter of a mating gear with T teeth is

$$D_b=\frac{p_n}{\pi}(T\sec\sigma+S_w)$$

where again S_w is a positive number that may have any value within a defined range, e.g. less than $4-\frac{10}{T}\cos^3\sigma$ and greater than $4-\frac{T}{10\cos^3\sigma}$. The designed working centre distance for such gears is

$$C=\tfrac{1}{2}(d_b+D_b)-\frac{2p_n}{\pi}$$

$$=\frac{p_n}{2\pi}[(t+T)\sec\sigma+S_p+S_w-4].$$

The reference diameters of the gears (those of the circles on which the normal pitch of the teeth is p_n) are

$$d_f=\left(\frac{p_n}{\pi}\sec\sigma\right)t \text{ and } D_f=\left(\frac{p_n}{\pi}\sec\sigma\right)T.$$

If $S_p+S_w-4=0$ the centre distance is $\frac{p_n}{2\pi}\sec\sigma\,(t+T)$, which is the sum of the radii of the reference circles and these therefore touch each other when the gears are meshed at the designed centre distance. If with $S_p+S_w-4=0$ the teeth of both gears have been cut exactly to full standard depth by means of a standard cutter, the gears mesh without backlash at the standard centre distance.

In practice gears are usually required to have some backlash and this is effected by cutting the teeth to something greater than standard depth. Teeth of exactly standard depth are a rarity.

The problem here is to devise a practical working formula for the backlash between full depth of gears meshed at the designed centre distance in the general case, where S_p+S_w-4 is not equal to zero. The rigorous method of doing so is straightforward but laborious, in that it demands use of tables of secants to five places of decimals and tables of the involute function to six places of decimals because the answer is the small difference between large quantities. The method is not accepted by anyone who realises that the quantity calculated is a "small difference" and that the rational way to determine it is by a "difference formula" demanding neither mathematical tables nor accuracy beyond normal slide rule working.

GEOMETRICAL DETAILS OF PROBLEM

Fig. 1 is a section of the pair of gears (numbers of teeth t and T) meshed at the designed centre distance by a "transverse plane" perpendicular to their axes. In this plane a tooth of the upper gear and an intertooth space of the lower gear are symmetrically disposed about the line of centres. The line 1 2 3 4 5 6 represents the section of the working part of the phantom standard rack that meshes simultaneously with both gears. The normal pressure angle of that rack is ψ_n(=20 deg.) and the transverse pressure angle is ψ_t. The pitch of the rack teeth in this plane is p_n sec σ and the radii of the meshing circles of the gears with it are therefore

$$O_1P_1=\frac{tp_n\sec\sigma}{2\pi}$$

and

$$O_2P_2=\frac{Tp_n\sec\sigma}{2\pi}.$$

The distance P_1P_2 is the difference between the designed centre distance and the sum of O_1P_1 and O_2P_2 and so

$$P_1P_2=\frac{p_n}{2\pi}(S_p+S_w-4). \quad . \quad (1)$$

The radii of the base circles of the involute profiles of the teeth are

$$O_1S_1=O_1P_1\cos\psi_t$$

and

$$O_2S_2=O_2P_2\cos\psi_t.$$

The points of contact of the rack tooth flank 23 with the involute profiles are Q_1 and Q_2, the intersections with 23 of the tangents P_1S_1 and P_2S_2 to the base circles. A common tangent to the base circles is U_1U_2 and the clearance between the involute profiles that touch 23 is V_1V_2. The problem is to

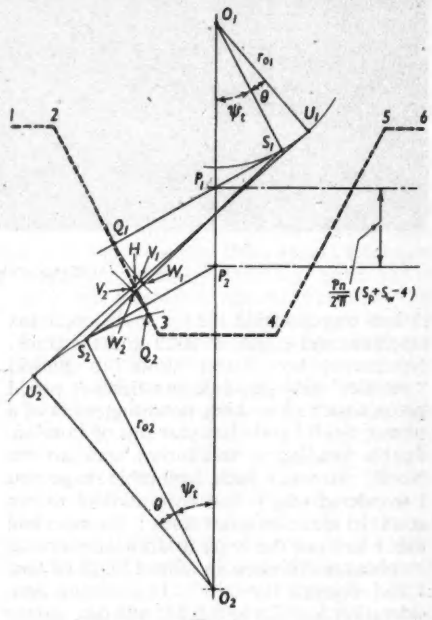


Fig. 1

evolve, in terms of p_n, ψ_n, t, T, S_p and S_w, an expression that gives V_1V_2 with adequate accuracy by slide rule working.

FIRST APPROXIMATION

If it be assumed that Q_1V_1 and Q_2V_2 are circular arcs of radii S_1Q_1 and S_2Q_2 respectively the problem has a simple solution that suffices for most practical cases. On this assumption the clearance between the profiles is the distance W_1W_2 between their intersections with the straight line S_1S_2.

Now

$$W_1W_2=S_1S_2-(S_1W_1+S_2W_2)$$

$$=\sqrt{S_1Y^2+Q_1Q_2^2}-(S_1Q_1+S_2Q_2)$$

$$=S_1Y\left[\sqrt{1+\left(\frac{Q_1Q_2}{S_1Y}\right)^2}-1\right]. \quad . \quad . \quad (2)$$

Here

$$S_1Y=O_1X=C\sin\psi_t$$

and

$$Q_1Q_2=P_1P_2\cos\psi_t=\frac{p_n}{2\pi}(S_p+S_w-4)\cos\psi_t.$$

Using the first two terms of the binomial expansion of the radical in (2) a first approximation is

$$W_1W_2=\frac{1}{2}\frac{(Q_1Q_2)^2}{S_1Y}=\frac{1}{2}\frac{(P_1P_2)^2\cos^2\psi_t}{C\sin\psi_t} \quad . \quad . \quad (3)$$

Now examination of the geometry of a flank of a rack tooth and a plane perpendicular to it and tangent to the base cylinder of the gear shows that

$$\left.\begin{aligned}\sin\psi_t&=\sin\psi_n\sec\sigma_0\\ \cos\psi_t&=\cos\psi_n\frac{\cos\sigma}{\cos\sigma_0}\end{aligned}\right\} \quad . \quad . \quad (4)$$

and

where σ is the helix angle of each gear at the reference cylinder, and σ_0 is the helix angle at the base cylinder. Using (1) and (4) in connection with (3), the result is that

$$W_1W_2=\frac{1}{8C}\left(\frac{p_n}{\pi}\right)^2(S_p+S_w-4)^2\frac{\cos^2\psi_n\cos^2\sigma}{\sin\psi_n\cos\sigma_0}.$$

Now the common tangent plane to the base cylinders is represented in Fig. 1 by U_1U_2 and the intersections of the tooth flanks with it are straight lines inclined to the axes of the gears at angle σ_0 and intersecting the plane of Fig. 1 in V_1V_2.

The normal clearance between the tooth flanks is therefore $V_1V_2\cos\sigma_0$ and, taking as a very close approximation, $V_1V_2=W_1W_2$, we have

Normal backlash

$$=2(W_1W_2)\cos\sigma_0$$

$$=\frac{1}{4C}\left(\frac{p_n}{\pi}\right)^2(S_p+S_w-4)^2\frac{\cos^2\psi_n}{\sin\psi_n}\cos^2\sigma \quad . \quad (5)$$

For British Standard tooth form, $\cos\psi_n=20$ deg. and so

Normal backlash

$$=\frac{0\cdot65}{C}(p_n/\pi)^2(S_p+S_w-4)^2\cos^2\sigma \quad . \quad . \quad . \quad (6)$$

Second Approximation

In the foregoing it was assumed that the arc Q_1W_1 is a circular one of radius S_1Q_1. The radius of curvature of Q_1V_1 actually changes from S_1Q_1 at Q_1 to U_1V_1 at V_1. The change is (very nearly) S_1U_1, which is equal to $r_{01}\theta$ and so the mean radius of curvature of Q_1V_1 is

$$S_1Q_1+\tfrac{1}{2}r_{01}\theta.$$

Hence

$$Q_1H=[S_1Q_1+\tfrac{1}{2}r_{01}\theta]\theta \text{ very nearly}$$

and similarly,

$$\begin{aligned}Q_1Q_2&=Q_1H+Q_2H\\&=[S_1Q_1+S_2Q_2+\tfrac{1}{2}(r_{01}+r_{02})\theta]\theta \quad . \quad (7)\end{aligned}$$

Now

$$S_1Q_1+S_2Q_2=S_1Y=C\sin\psi_t$$

$$=\frac{p_n}{2\pi}[(t+T)\sec\sigma+S_p+S_w-4]\sin\psi_t$$

and

$$r_{01}=O_1S_1=O_1P_1\cos\psi_t=\frac{p_n}{2\pi}t\sec\sigma\cos\psi_t$$

$$\begin{aligned}r_{01}+r_{02}=O_1S_1+O_2S_2&=(O_1P_1+O_2P_2)\cos\psi\\&=\frac{p_n}{2\pi}(t+T)\sec\sigma\cos\psi_t.\end{aligned}$$

As before,

$$Q_1Q_2=P_1P_2\cos\psi_t=\frac{p_n}{2\pi}(S_p+S_w-4)\cos\psi_t.$$

Hence (7) becomes, with some rearrangement,

$$\left(\frac{S_p+S_w-4}{t+T}\right)\cos\sigma$$

$$=\theta\left[1+\left(\frac{S_p+S_w-4}{t+T}\right)\cos\sigma\right]\tan\psi_t+\frac{\theta^2}{2}$$

or

$$\theta^2+2\tan\psi_t(1+z)\theta-2z=0 \quad . \quad . \quad (8)$$

where

$$z=\left(\frac{S_p+S_w-4}{t+T}\right)\cos\sigma \quad . \quad . \quad (9)$$

and

$$\theta=-(1+z)\tan\psi_t\pm\sqrt{[(1+z)^2\tan^2\psi_t+2z]}$$

or

$$\theta=(1+z)\tan\psi_t\left[-1\pm\sqrt{\left[1+\frac{2z\cot^2\psi_t}{(1+z)^2}\right]}\right].$$

Taking the first three terms of the binomial expansion of the radical, this becomes

$$\theta=\frac{z\cot\psi_t}{1+z}-\frac{1}{2}\frac{z^2}{(1+z)^3}\cot^3\psi_t \quad . \quad (10)$$

Now in the expression (3) for W_1W_2 (the clearance between the profiles in the transverse section), S_1Y is the sum of the (assumed) radii of curvature S_1Q_1 and S_2Q_2 of the profiles.

In the closer approximation now required the mean radius of curvature between Q_1 and V_1 is $S_1Q_1+\frac{1}{2}r_{01}\theta$ and that between Q_2 and V_2 is $S_2Q_2+\frac{1}{2}r_{02}\theta$.

The sum of these is $S_1Q_1+S_2Q_2+\frac{1}{2}(r_{01}+r_{02})\theta=S_1Y+\frac{1}{2}(r_{01}+r_{02})\theta$.

Hence the S_1Y in (3) is now to be replaced by

$$S_1Y+\tfrac{1}{2}(r_{01}+r_{02})\theta.$$

Now

$$S_1Y=\frac{p_n}{2\pi}(t+T)\sec\sigma\left[1+\frac{S_p+S_w-4}{t+T}\cos\sigma\right]\sin\psi_t$$

Now

$$r_{01}+r_{02}=\frac{p_n}{2\pi}(t+T)\sec\sigma\cos\psi_t=\frac{S_1Y\cot\psi_t}{1+z}.$$

Hence the denominator of (3) and (5) is to be multiplied by

$$1+\frac{1}{2}\frac{(r_{01}+r_{02})}{S_1Y}\theta=1+\frac{\theta}{2}\frac{\cot\psi_t}{1+z},$$

and from (10) this is equal to

$$1+\frac{z}{2}\frac{\cot^2\psi_t}{(1+z)^2}-\left(\frac{z}{2}\frac{\cot^2\psi_t}{(1+z)^2}\right)^2.$$

Now in (5)

$$(S_p+S_w-4)^2\cos^2\sigma=z^2(t+T)^2.$$

Making this substitution, multiplying numerator and denominator by C and writing

$$C=\left(\frac{p_n}{2\pi}\right)\sec\sigma[t+T+(S_p+S_w-4)\cos\sigma]$$

$$=\frac{p_n}{2\pi}\sec\sigma(t+T)[1+z]$$

we have, as equivalent to (5)

Normal backlash (first approx.)

$$=\frac{z^2C}{(1+z)^2}\frac{\cos^2\psi_n}{\sin\psi_n}\cos^2\sigma.$$

This was derived from (3), which was based on the first two terms of the expansion of the radical in (2). Taking an extra term, we have remaining

$$\frac{1}{2}\left(\frac{Q_1Q_2}{S_1Y}\right)^2-\frac{1}{8}\left(\frac{Q_1Q_2}{S_1Y}\right)^4$$

instead of

$$\frac{1}{2}\left(\frac{Q_1Q_2}{S_1Y}\right)^2.$$

In other words there is now a correction factor of

$$1-\left(\frac{Q_1Q_2}{2S_1Y}\right)^2$$

which is equal to

$$1-\left(\frac{z\cot\psi_t}{2(1+z)}\right)^2.$$

The corrected value for normal backlash is therefore

$$z^2C\frac{\cos^2\psi_n}{\sin\psi_n}\cos^2\sigma$$

multiplied by

$$\frac{1-\left(\frac{z}{2(1+z)}\cot\psi_t\right)^2}{(1+z)^2\left[1+\frac{z}{2}\frac{\cot^2\psi_t}{(1+z)^2}-\left(\frac{z}{2}\frac{\cot^2\psi_t}{(1+z)^2}\right)^2\right]}$$

and this, limited to the second power of z, becomes

$$\frac{1}{1+z\left(2+\frac{\cot^2\psi_t}{2}\right)+z^2\left[1+\frac{\cot^2\psi_t}{4(1+z)^2}-\frac{1}{4}\frac{\cot^4\psi_t}{(1+z)^2}\right]}.$$

Hence

Normal backlash=

$$\frac{z^2C\cos^2\sigma\cos^2\psi_n\operatorname{cosec}\psi_n}{1+z\left[2+\frac{(\cot\psi_n\cos\sigma)^2}{2}\right]+z^2\left[1+\frac{(\cot\psi_n\cos\sigma)^2}{4(1+z)^2}-\frac{1}{4}\frac{(\cot\psi_n\cos\sigma)^4}{(1+z)^2}\right]} \quad . \quad . \quad (11)$$

and for $\psi_n=20$ deg. this becomes

Normal backlash

$$=\frac{2\cdot58z^2C\cos^2\sigma}{1+z(2+3\cdot78\cos^2\sigma)+z^2[1+1\cdot9\cos^2\sigma-14\cdot3\cos^4\sigma]} \quad . \quad . \quad . \quad . \quad . \quad (12)$$

For straight teeth ($\sigma=o$) this becomes

$$\text{Normal backlash}=\frac{2\cdot58z^2C}{1+5\cdot78z-11\cdot4z^2}\text{ very nearly.}$$

Comparison of the value of this expression and the accurately calculated one in each of a number of extreme cases indicates that closer approximation is afforded by the slightly modified expression

Normal backlash for B.S. spur gears with $\psi=20$ deg.

$$=\frac{2\cdot58z^2C}{1+6z-16z^2}=\frac{z^2C}{6\cdot2[0\cdot125+z][0\cdot5-z]} \quad . \quad . \quad . \quad . \quad (13)$$

Similar adjustment of (12) leads to :—

Normal backlash for B.S. helical gears with $\psi_n=20$ deg.

$$=\frac{2\cdot58z^2C\cos^2\sigma}{1+z(2+4\cos^2\sigma)-z^2\left[\frac{20}{(1+z)^3}\cos^4\sigma-1\right]} \quad . \quad . \quad . \quad . \quad . \quad (14)$$

In any practical case the calculation of backlash by use of (12) or (14) can always be effected with adequate accuracy by means of a standard 10in slide-rule, with very a small fraction of the effort required for the rigorous methods and without using any tables. This is made clear by the example given below.

Numerical Example (Linear Dimensions in Inches)

To determine the backlash between a pair of equal helical gears with teeth generated to full depth by a British Standard cutter in accordance with the following dimensions :

Number of teeth	4
Normal pitch of cutter	3·1416 (1.D.P.)
Axial pitch	3·1416 cosec 45 deg.

$S_p=S_w=3$.

As the axial pitch is equal to the normal pitch multiplied by cosec 45 deg., the helix angle at the reference cylinder is 45 deg.

Hence, reference diameter $d_r=(4/1)$ sec 45 deg.$=5\cdot657$.

Denoting the transverse pressure angle at the reference cylinder by ψ_t we have $\tan\psi_t=\tan\psi_n \sec 45$ deg.$=\tan 20$ deg. $\sec 45$ deg. $=0\cdot5147$.

Hence,

from tables $\psi_t=27$ deg. 14·1 min
and $\sec\psi_t=1\cdot1247$.

Hence,

$$\text{Base diameter}=d_r\cos\psi_t=\frac{5\cdot657}{1\cdot1247}=5\cdot030.$$

$$\text{Blank diameter } d_b=\frac{p_n}{\pi}(t\sec\sigma+S_p)$$
$$=1[5\cdot657+3]=8\cdot657.$$

$$\text{Centre distance } =\tfrac{1}{2}(d_b+D_b)-\frac{2p_n}{\pi}$$
$$=8\cdot657-2=6\cdot657.$$

As the gears are equal, the meshing diameter d_m is equal to the centre distance, i.e. $d_m=6\cdot657$.

As the gears are equal, the common phantom rack is symmetrically situated in relation to them when they are fully meshed. Hence, at a plane that touches the meshing cylinders, the normal space width of the rack is half the normal pitch, i.e. 1·5708. The parallel plane that touches the reference cylinder is nearer to the axis than this by 0·5 and so

Normal space width of rack at reference plane
$=1\cdot5708+2\times0\cdot5\tan 20$ deg.
$=1\cdot9348$.

Transverse space width (PQ in Fig. 2)
$=1\cdot9348\sec 45$ deg$=2\cdot7358$.

This is equal to the transverse tooth thickness of the gear at radius $\frac{1}{2}d_r=2\cdot8285$.

Angular tooth thickness at radius 2·8285

$$=\frac{2\cdot7358}{2\cdot8285}=0\cdot9673 \text{ radians.}$$

The angular tooth thickness at the meshing cylinder is less than this by twice the difference between the involute function of the transverse pressure angle at the meshing circle and that for the reference circle.

Denoting the transverse pressure angle at the meshing cylinder by ψ_{tm}

$$\frac{\sec\psi_{tm}}{\sec\psi_t}=\frac{\text{meshing diameter}}{\text{reference diameter}}$$

whence

$$\text{Sec }\psi_{tm}=\frac{6\cdot657}{5\cdot657}\times1\cdot1247=1\cdot3232.$$

Hence,

from tables $\psi_{tm}=40$ deg. 54·7 min.

Again from six-figure tables, with interpolation

inv. 40 deg. 54·7 min$=0\cdot15253$

and

inv. 27 deg. 14·1 min$=0\cdot03937$.

Hence,

Angular tooth thickness at radius 3·3285
$=0\cdot9673-2[0\cdot15253-0\cdot03937]$
$=0\cdot7410$.

If there were no backlash, the tooth thickness of each of two identical gears at the meshing circle would be equal to half the pitch and this expressed in radians is 2π divided by twice the number of teeth or, in this case $\pi/4=0\cdot7854$.

The deficiency in angular tooth thickness of each gear is therefore $0\cdot7854-0\cdot7410=0\cdot0444$, which means a total angular backlash of 0·0888 radians. This is expressed as a circumferential play at the base circle by multiplying by $\frac{1}{2}\times5\cdot030$. This is referred to the direction perpendicular to the base spiral (and therefore normal to the tooth surfaces at any radius) by multiplying by $\cos\sigma_0$.

Now

$$\tan\sigma_0=\frac{\text{circumference of base cylinder}}{\text{lead of teeth}}$$
$$=\frac{\pi d_0}{tp_a}$$
$$=\frac{\pi\times5\cdot030}{4\times\pi\text{ cosec }45\text{ deg.}}$$
$$=0\cdot88905.$$

Hence,

from tables $\sigma_0=41$ deg. 43 min

and

$$\cos\sigma_0=0\cdot74644.$$

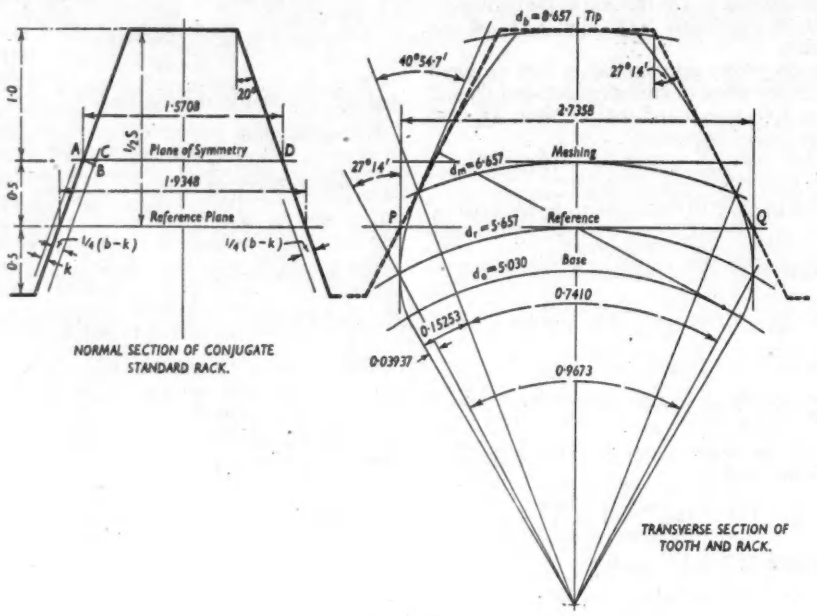


Fig. 2

Thus,

Normal backlash $0\cdot0888\times2\cdot515\times0\cdot74644$
$=0\cdot167$.

By contrast with this process, in which it is necessary in many places to work to at least five significant figures, slide-rule working suffices for the following :—

$$z=\frac{S_p+S_w-4}{t+T}\cos\sigma=\frac{3+3-4}{4+4}\cos 45\text{ deg.}$$
$$=0\cdot177.$$

From (12) deriving the numerical values of trigonometrical functions from the ordinary slide-rule scales,

$$\text{Normal backlash}=\frac{0\cdot177^2\times6\cdot657\times\cos^3 45\text{ deg.}\times\cos^2 20\text{ deg.}\times\text{cosec }20\text{ deg.}}{1+0\cdot177[2+3\cdot78\cos^2 45\text{ deg.}]+0\cdot177^2[1+1\cdot9\cos^2 45\text{ deg.}-14\cdot3\cos^4 45\text{ deg.}]}$$
$$=\frac{0\cdot209\times0\cdot5\times0\cdot94^2\times2\cdot92}{1+0\cdot177\times3\cdot89+0\cdot177^2\times(-1\cdot63)}$$
$$=0\cdot165.$$

Thus, even in this most unusually extreme case, the approximate method gives a backlash figure that differs from the rigorously calculated one by less than one-thousandth of the normal pitch and this is an acceptable tolerance on backlash.

The condition of " no backlash " normally required and tolerable only in instrument gears, cannot be achieved simply by control of dimensions in manufacture as it would imply zero tolerance on at least three dimensions. In practice it is a condition of negative backlash accommodated by elastic deformation of gears and mounting.

General Case

The foregoing numerical example refers to the special case of equal gears. The numbers of teeth in wheel and pinion are usually different and the rigorous procedure for calculating the normal backlash then requires about twice as much calculation as is shown above. The approximate method, on the other hand, requires no extra labour at all.

Caliper Settings

The normal backlash k only rarely coincides with the desired backlash b and so gear teeth are only rarely cut exactly to standard depth. It is not usual to rely on measurement of depth of cut as a means of measuring tooth thickness ; that dimension is usually measured directly by use of gear-tooth calipers. The caliper settings for full-depth teeth are :

$$\left.\begin{aligned}\text{Thickness } g&=(0\cdot321S+0\cdot745)(p_n/\pi)\\ \text{Height } \quad h&=(0\cdot442S-0\cdot137)(p_n/\pi)\end{aligned}\right\}\quad(15)$$

From the left-hand diagram in Fig. 2 it will be seen that to produce backlash b instead of k the surface of each of the mating flanks must be displaced by $\frac{1}{2}(b-k)$ measured perpendicular to its tangent plane. The tooth thickness as measured by caliper on the line AD, is therefore reduced by $2AC=2AB$ sec ψ_n or for British Standard teeth,

$$\tfrac{1}{2}(b-k)\sec 20\text{ deg}=0\cdot53(b-k).$$

This applies to both the mating gears. In general, therefore, g is less than the amount specified in (15) by $0\cdot53\,(b-k)$.

Backlash in Internal Gears

The general principles described above apply to internal gears with the changes noted below.

(1) $D_b=\frac{p_n}{\pi}(T\sec\sigma-S_t)$,

where S_t is a quantity not less than 2 and not greater than either 4 or $T/10$.

$$(2)\quad z=\left(\frac{S_p+S_t-4}{T-t}\right)\cos\sigma.$$

(3) Normal backlash

$$\frac{-z^3C\cos^3\sigma\cos^2\psi_n\operatorname{cosec}\psi_n}{1-z\left[2+\frac{\cot^2\psi_n\cos^2\sigma}{2}\right]+z^2\left[1+\frac{(\cot\psi_n\cos\sigma)^2}{2}+\frac{(\cot\psi_n\cos\sigma)^4}{4}\right]} \quad . \quad . \quad . \quad . \quad . \quad (16)$$

and for $\psi_n=20$ deg. this becomes

Normal backlash

$$=\frac{-2\cdot58z^3C\cos^3\sigma}{1-z(2+3\cdot78\cos^2\sigma)+z^2(1+3\cdot78\cos^2\sigma+14\cdot3\cos^4\sigma)} \quad . \quad . \quad . \quad . \quad . \quad (17)$$

For straight teeth ($\sigma=0$) this becomes

Normal backlash

$$=\frac{-2\cdot58z^3C}{1-5\cdot78z+19z^2}.$$

It is to be noted that unless $S_p+S_t=0$, the normal backlash of internal gears is negative in all cases. This means that the teeth must be cut to a depth greater than standard depth even to secure zero backlash.

Crossed Helical Gears

In full-depth helical gears meshed on non-parallel non-intersecting axes at the designed centre distance, the normal backlash is zero in every case provided that the widths of the gears are great enough to ensure continuity of tooth action.

This is because the lines of contact of mating teeth with a common flank of the phantom rack are not parallel, their point of intersection at any phase of engagement being the point of contact between the mating teeth.

The effect of making S_p+S_w-4 different from zero is not to produce backlash between full-depth teeth of crossed helical gears but only to change the position of the contact-paths of the two sets of mating tooth-flanks.

Theory of Restrained Corrugated Diaphragms

By C. B. FLINDT, B.A., A.M.I.E.E.

The corrugated metal diaphragm has been used for many years as the basis of measuring instruments, in which the force due to fluid pressure is balanced by the stresses set up in the metal as it deflects. Many theoretical studies have been published which seek to explain the behaviour of such diaphragms, but only those dealing with linear deflections have been very successful. In this article the theory of linear diaphragms, originally due to J. A. Haringx,[1] is developed with the purpose of calculating the thrust which can be exerted by a restrained diaphragm under uniform pressure conditions.

THE corrugated metal diaphragms to be considered fall into two categories—fully-restrained or semi-restrained. The former type is used in force-balance instruments, in which a servo-mechanism is used to apply load automatically to a diaphragm as it attempts to deflect. The movement of the diaphragm is thus limited to a very small deflection about its zero position, sufficient only to operate the detector element of the loading mechanism. The load applied is a measure of the pressure acting on the diaphragm and is directly related to it. The semi-restrained diaphragm is used in such devices as pressure-reducing valves, in which the pressure load is balanced by a strong spring, but a substantial deflection is allowed to take place.

It has been observed that the effective force producing area of such diaphragms is very much less than the projected area, unlike bellows which have almost identical effective and projected areas. This is due to the diaphragm distorting, and some of the force due to the pressure being expended in balancing the stresses set up in the metal. These stresses are very much less in the case of a bellows, which does not usually have sufficient rigidity to support the end thrust unaided.

In the following analysis it will be shown that the effective area of a diaphragm depends on the area of the rigid central portion and the moment of inertia of the corrugations. In the course of the mathematics, the deflection of a free diaphragm under concentrated loading will also be developed.

Theoretical Development

The mathematical theory is based on a paper by J. A. Haringx,[1] which deals with non-restrained diaphragms loaded by a uniform pressure only. For a full description of the assumptions made and the development of the basic theory, the reader is referred to the original paper; and to facilitate cross reference, the original symbols have been retained, whenever possible, in this article. The present analysis will be limited to the case where the diaphragm is sufficiently thick for the distortion of corrugations, due to deflection, to be neglected. For the unrestrained diaphragm Haringx finds this to be true for material thicknesses in excess of

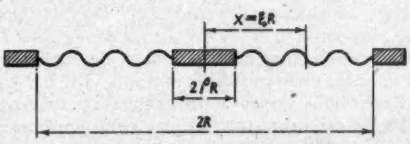


Fig. 1—Cross section of corrugated diaphragm

0·2 per cent of the diaphragm diameter. Since deflections of the restrained diaphragm will be considerably smaller, with correspondingly less distortion, it is reasonable to suppose that the theory will hold good for reduced thicknesses. The downward extension of the thickness range has not, however, been investigated practically.

The diaphragm (Fig. 1) is assumed to have a number of concentric corrugations of identical form and to be held clamped at $\xi=1$ by a rigid outer rim. The central area is held by a rigid plate at $\xi=\rho$. By consideration of the forces acting on a single corrugation, of dimensions shown in Fig. 2, Haringx deduces an equation which defines the rotation of a small element of a fictitious flat plate whose deflection will be similar to that of the diaphragm. The equation relating ψ, the angle of rotation of the element, and ξR the distance of the element from the centre of the plate is :—

$$\xi^2\frac{d^2\psi}{d\xi^2}+\xi\frac{d\psi}{d\xi}-q^2\psi=-\frac{DR^2}{E'I_r}\xi^2 \quad . \quad . \quad (1)$$

In this equation

$$q^2=\frac{EI_t}{E'I_r}=\frac{I_t}{(1-\nu^2)I_r} \quad . \quad . \quad . \quad (2)$$

E=Young's Modulus for the diaphragm material.

$E'=E(1-\nu^2)$ where ν is Poisson's Ratio.

$I_t=\int\zeta^2dF$ (see Fig. 2).

$I_r=h^3l/12S$ where $2S$ is the arc length of a corrugation.

q^2 is, therefore, the ratio of the rigidity of the corrugation, with respect to bending about a radius, to that with respect to bending about an axis perpendicular to the meridian

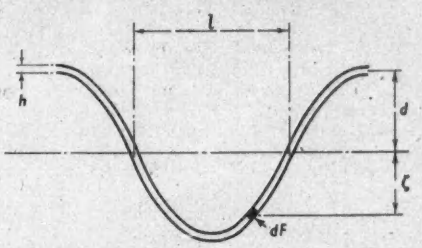


Fig. 2—Cross section of typical corrugation

plane. D is the transverse force, per unit length of circumference, acting on the edge of element. The vertical deflection of the inner rim of the diaphragm, relative to the outer edge, is given by :—

$$f=R\int_\rho^1\psi d\xi \quad . \quad . \quad . \quad . \quad (3)$$

For uniform pressure loading p per unit area, $D=\frac{1}{2}pR\xi$, and for a load W, concentrated at the centre of the diaphragm, $D=W/2\pi\xi R$. If these expressions are substituted in (1), the resulting equation will define the case of a diaphragm subject to both a uniform pressure load and a central concentrated load.

$$\xi^2\frac{d^2\psi}{d\xi^2}+\xi\frac{d\psi}{d\xi}-q^2\psi=-\frac{1}{2}\frac{pR^2}{E'I_r}\xi^3-\frac{WR}{2\pi E'I_r}\xi \quad . \quad . \quad . \quad . \quad (4)$$

The solution of this equation is given by :

$$\psi=C_1\xi^{-q}+C_2\xi^q+A\xi^3+B\xi \quad . \quad (5)$$

where

$$A=\frac{pR^3}{2(q^2-9)E'I_r},\quad B=\frac{WR}{2\pi(q^2-1)E'I_r}.$$

Substituting the boundary conditions :

$\psi=0$ when $\xi=1$.

$\psi=0$ when $\xi=\rho$.

in equation (4),

$$C_1=\frac{-A(1-\rho^{q+3})}{(1-\rho^{2q})}-\frac{B(1-\rho^{q+1})}{(1-\rho^{2q})}.$$

$$C_2=\frac{-A\rho^{q+3}(1-\rho^{q-3})}{(1-\rho^{2q})}-\frac{B\rho^{q+1}(1-\rho^{q-1})}{(1-\rho^{2q})}.$$

Integrating equation (5), inserting the limits, and simplifying, the equation for f is obtained :

$$f=\frac{pR^4(1-\rho^4)}{8E'I_r(q+1)(q+3)}\left[1-\frac{8q\rho^3(1-\rho^{q-1})(1-\rho^{q-3})}{(q-1)(q-3)(1-\rho^4)(1-\rho^{2q})}\right]-\frac{WR^3(1-\rho^2)}{4\pi E'I_r(q+1)^2}\left[1-\frac{4q\rho^3(1-\rho^{q-1})^2}{(q-1)^2(1-\rho^{2q})(1-\rho^2)}\right] \quad . \quad . \quad . \quad . \quad (6)$$

This may be expressed as

$$f=\frac{p\pi R^4}{4\pi E'I_r}\phi_1(q\rho)+\frac{WR^2}{4\pi E'I_r}\phi_2(q\rho) \quad . \quad (7)$$

If the diaphragm is fully restrained $f=0$ and

$$-\frac{W}{p\pi R^2}=\frac{\phi_1(q\rho)}{\phi_2(q\rho)}=G \quad . \quad . \quad . \quad (8)$$

G is the " Equivalent Piston Factor " and is defined as the factor by which the projected area of the diaphragm must be multiplied in order to obtain the area of the piston which would exert an equivalent thrust when subject to the same pressure. It should be noted that G is virtually independent of diaphragm material, since Poisson's ratio is

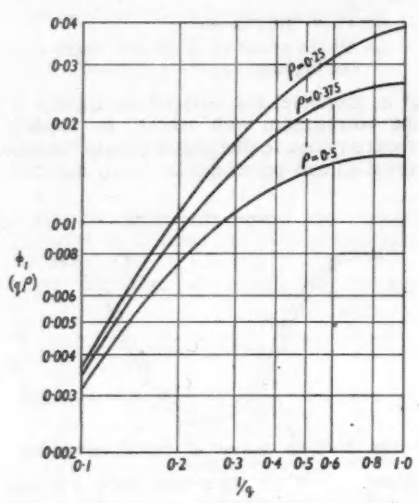


Fig. 3

similar for most metals and independent of the precise contour of the corrugation.

For a spring restrained diaphragm the external concentrated load will be wf, where w is the spring rate.

Substituting in (7) above

$$f=\frac{p\pi R^4}{4\pi E' I_r}\phi_1(q\rho)+\frac{wfR^2}{4\pi E' I_r}\phi_2(q\rho)$$

whence

$$f=\frac{p\pi R^4\phi_1(q\rho)}{4\pi E' I_r-wR^2\phi_2(q\rho)} \quad . \quad . \quad . \quad (9)$$

The equations (7), (8) and (9) enable loads and deflections to be calculated for a wide range of diaphragm conditions. If $W=0$, the reduced equation (7) corresponds to that

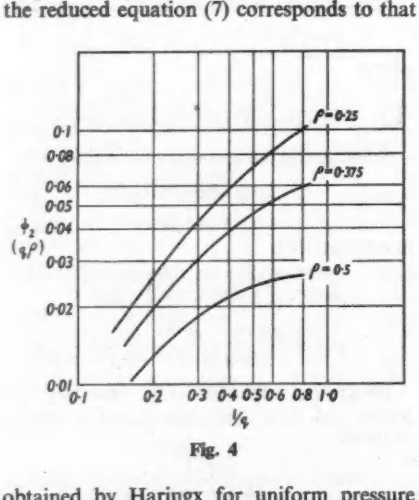


Fig. 4

obtained by Haringx for uniform pressure loading only. Also, if p is put equal to 0, equation (7) gives the deflection of a free diaphragm under a concentrated central load. If equation (8) is allowed to tend to the limits ($\rho\to 0$, $q\to 1$) we obtain the value of G for a flat plate, $G=0{\cdot}25$. This agrees with the value obtained by normal flat plate theory. In Figs. 3 and 4 $\phi_1(q\rho)$ and $\phi_2(q\rho)$ respectively are plotted against $1/q$ for various values of ρ. The values obtained for G are plotted in Fig. 5 and are generally in agreement with the experimental results obtained by Wildhack and Goerke,[2] although somewhat higher.

Design Application

To illustrate the use of the theory a diaphragm will be designed to meet the following specification. A fully restrained diaphragm is required to exert a force equivalent to a piston of 1·2 square inches area. The fluid pressure will not exceed 30 lb per square inch, but the diaphragm must not be damaged if accidentally subjected to full pressure without restraint. The space available for the diaphragm cannot exceed 1·8in diameter.

Since the theory holds good for all shapes of corrugation, it is convenient to choose the well-known N.A.C.A. form described in reference.[3] This corrugation is constructed from circular arcs and its geometry lends itself to ease of calculation. It can be shown that

$$R/l=8,\ d/l=0{\cdot}134,\ S/l=1{\cdot}047$$

and

$$q^2=1{\cdot}08+6{\cdot}34\frac{d^2}{h^2} \quad . \quad . \quad . \quad . \quad (10)$$

Considering first the maximum available diameter 1·8in, the projected area would be 2·54 square inches. Therefore

$$G\,\text{min}=1{\cdot}2/2{\cdot}54=0{\cdot}474.$$

In order to allow some latitude in design a diameter slightly smaller than the maximum should be chosen. Let $G=0{\cdot}49$ when $R=0{\cdot}883$in and from Fig. 5 $q=5$ and $\rho=0{\cdot}375$. From the geometrical constants given above, $R/d=8/0{\cdot}134$, $d=0{\cdot}017R$.

Substituting this in equation (9),

$$q^2=1{\cdot}08+18{\cdot}4\times10^{-4}\frac{R^2}{h^2}.$$

If

$$q=5,\ \frac{R^2}{h^2}=\frac{23{\cdot}92\times10^4}{18{\cdot}4}.$$

Whence

$$R/h=114.$$

Substituting

$$R=0{\cdot}883,\ h=0{\cdot}00765\text{in}.$$

The nearest available thickness of steel strip was 0·0076in.

It is next necessary to decide whether this material thickness would meet the strength requirement.

A rough empirical rule can be derived from the researches of Wildhack and Goerke[2] on diaphragms under uniform pressure loading. They found that the linearity of a diaphragm for which $\rho=0{\cdot}25$ was maintained up to a deflection of $0{\cdot}04R$. They also established that such diaphragms could be used up to deflections of about $0{\cdot}08R$ without overstraining the material. For other values of ρ it is reasonable to multiply these figures by a factor K defined by

$$K=\frac{\phi_1(q\rho_1)}{\phi_1(q\rho_0)}$$

where $\rho_0=0{\cdot}25$ and ρ_1 is the value of ρ for the diaphragm under consideration. It would also appear reasonable to assume that if the deflection does not exceed the linear range when the pressure is half its maximum value, then the diaphragm will not be overstrained under normal operating conditions. Summarising, the linear range is assumed to extend to $0{\cdot}04KR$ and the maximum safe deflection to be $0{\cdot}08KR$. If the deflection is less than $0{\cdot}04KR$ when $p=\frac{1}{2}p\ max.$, the diaphragm is assumed to be safely stressed.

Applying these assumptions to the diaphragm design arrived at above, the maximum pressure is to be 30 lb per square inch.

$$\rho_1=0{\cdot}375,\ q=5.$$

From Fig. 3,

$$\phi_1(q\rho_0)=0{\cdot}011$$
$$\phi_2(q\rho_1)=0{\cdot}0092.$$

Therefore

$$K=0{\cdot}83.$$

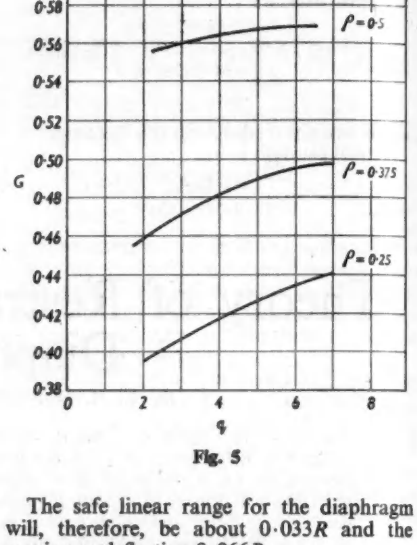


Fig. 5

The safe linear range for the diaphragm will, therefore, be about $0{\cdot}033R$ and the maximum deflection $0{\cdot}066R$.

When $p=\frac{1}{2}p\ max.$, $=15$ lb per square inch, f can be calculated from equation (7), assuming $W=0$.

$$f=\frac{p\pi R^4}{4\pi E' I_r}\phi_1(q\rho).$$

E for steel is taken as 30×10^6, $\nu=0{\cdot}3$.

$$I_r=\frac{(0{\cdot}0076)^3}{12}\times\frac{1}{1{\cdot}047}.$$

$$I_r=35\times10^{-9}.$$

$\phi=0{\cdot}0092$ from Fig. 3.

Therefore,

$$f=\frac{15\times(0{\cdot}883)^4\times0{\cdot}0092}{4\times27{\cdot}3\times35\times10^{-3}}.$$

$$f=0{\cdot}022\text{in}.$$

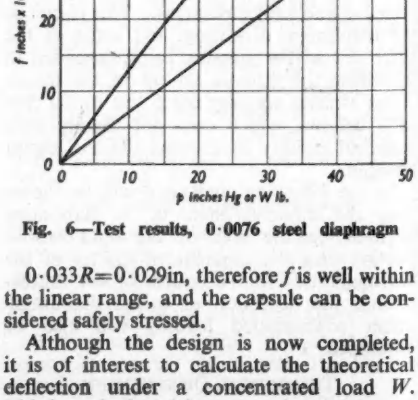


Fig. 6—Test results, 0·0076 steel diaphragm

$0{\cdot}033R=0{\cdot}029$in, therefore f is well within the linear range, and the capsule can be considered safely stressed.

Although the design is now completed, it is of interest to calculate the theoretical deflection under a concentrated load W. This is again found from equation (7), assuming, in this case, that $p=0$.

$$f=\frac{WR^2}{4\pi E' I_r}\phi_2(q\rho).$$

Taking $W=15$ lb and substituting $\phi_2(q\rho)=0{\cdot}0195$ from Fig. 4:—

$$f=0{\cdot}0193\text{in.}$$

A diaphragm was constructed, using the dimensions calculated above, out of 0·0076in, 0·8 per cent carbon steel. The deflection curves found for this diaphragm are shown in Fig. 6. The effective piston area was found to be 1·18 square inches, which was within 2 per cent of the design figure. The correspondence between calculated and test results for deflection under load was also very good, as shown in the table below :

	Calculated	Test result	Error, per cent
Deflection at 15 lb per square inch	0·022	0·0217	+1·5
Deflection at 15 lb load ...	0·0193	0·0190	+1·5
Limit of linearity	0·029	0·026	+10

It is also interesting to note that the effective piston area, as derived from the relative slopes of the two curves taken at the same deflection, remains constant within 5 per cent over the whole range of test. Since the deflection had become very non-linear at its upper limit, this is a useful verification of the assumption that the shape of the corrugation did not greatly influence the value of G, and hence that the extension of the theory to thickness less than 0·2 per cent of diaphragm diameter should be possible.

Conclusion

The theory has been found to produce results which are in excellent agreement with the test figures in the few cases actually investigated by the author. Future work should be devoted to testing the theory in as many cases as possible, and particularly to investigation of the extent to which it is applicable to very thin diaphragms.

The author wishes to thank the directors of Short Brothers and Harland, Ltd., Belfast, for permission to publish this paper ; the directors of Teddington Controls, Ltd., Merthyr Tydfil, for permission to include some of the work originally carried out to their instructions, and finally Martinus Nijhoff, for permission to reproduce equations (1), (2), (3) and (10), which originally appeared in reference.[1]

References

[1] Haringx, J. A., "The Rigidity of Corrugated Diaphragms." *Applied Scientific Research*, Vol A2 (1950), M. Nijhoff, The Hague.
[2] Wildhack, W. A., and V. H. Goerke, "Corrugated Metal Diaphragms for Aircraft Pressure Measuring Instruments." National Advisory Committee for Aeronautics, Technical Note No. 738, 1939.

Control System Nomogram

By R. H. MACMILLAN*

If the open-loop response of a single-loop linear control system to a sinusoidal disturbance of unit amplitude has an amplitude r and a phase displacement θ, it can be represented by the vector $re^{i\theta}$. When the loop is closed, then provided there is unity transfer in the feedback path, the output response to a sinusoidal input disturbance of unit amplitude will be represented by the vector $Me^{i\phi}$, where M is the overall dynamic magnification of the system.

It can be shown that

$$Me^{i\phi}=\frac{re^{i\theta}}{1+r^{i\theta}} \quad \ldots\ldots\ldots \quad (1)$$

When making frequency response tests and when performing preliminary design calculations, it would often be convenient to evaluate M for specified values of r and θ, without the necessity for drawing response diagrams. This can be done by means of a nomogram, which is obtainable by manipulating equation (1) suitably. Thus we have

$$\frac{1}{M}e^{-i\phi}=1+\frac{1}{r}e^{-i\theta}$$

$$=\left(1+\frac{1}{r}\cos\theta\right)-i\left(\frac{1}{r}\sin\theta\right)$$

whence

$$\frac{1}{M^2}=\left(1+\frac{1}{r}\cos\theta\right)^2+\left(\frac{1}{r}\sin\theta\right)^2$$

$$=\left(1+\frac{1}{r^2}\right)+\frac{2}{r}\cos\theta \quad \ldots\ldots \quad (2)$$

It is now possible to construct the nomogram with two straight parallel scales graduated linearly in $1/M^2$ and $\cos\theta$, the scale for r being curved, as in Fig. 1. If a straight line on this chart passes through the appropriate values of r and θ it will cut the third scale at the desired value of M.

In practical applications it is often of interest to obtain the maximum value of M, normally greater than unity, which will usually occur when θ lies between -180 ± 60. A chart for these more limited scales is given in Fig. 2.

* Department of Engineering, Cambridge University.

It will be noted that equation (1) can be written

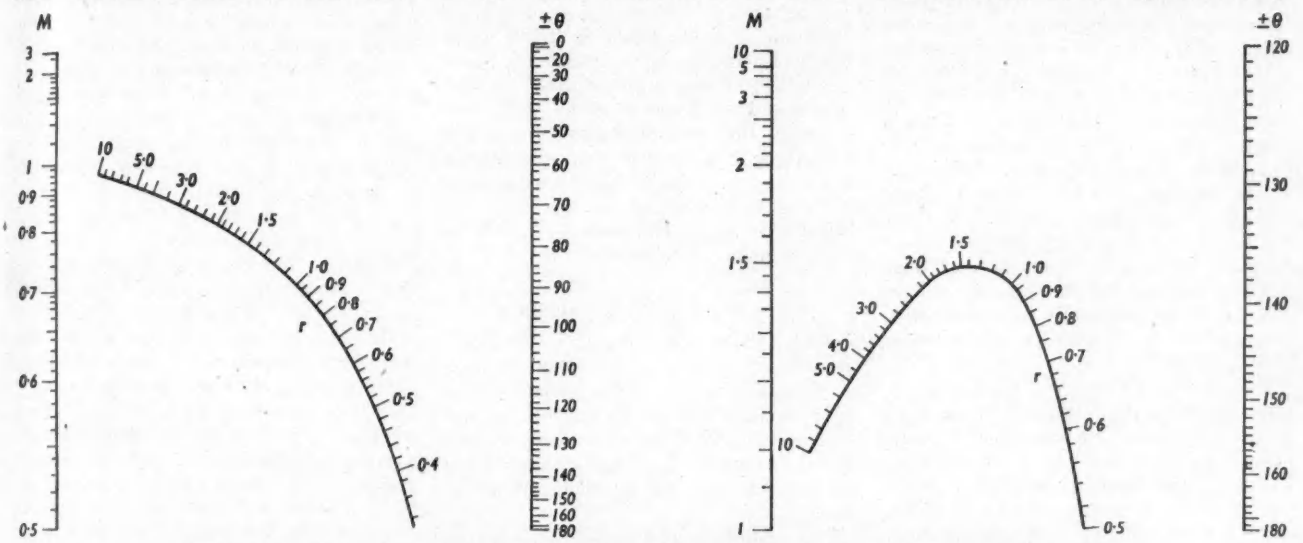
$$re^{i\theta}=\frac{Me^{i\phi}}{1-Me^{i\phi}}$$

whence

$$re^{i(\theta+\pi)}=\frac{Me^{i(\phi+\pi)}}{1+Me^{i(\phi+\pi)}} \quad \ldots \quad (3)$$

Since this equation is identical in form with equation (1), which is satisfied by the nomograms, it will be seen that if r is read on the M-scale and M is read on the r-scale, then the corresponding angle on the θ-scale is $(\phi+\pi)$. Thus the value of ϕ can be obtained from the same charts, after M has first been found from them.

Since the method of construction of these charts has been outlined, it is possible for anyone so minded to make further diagrams covering any other desired part of the range. It is thought that such charts could be of material assistance to the control engineer.



Figs. 1 and 2—Nomograms for evaluating the overall dynamic magnification of control systems, in terms of r and θ.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

NOTCH DUCTILE STEEL FOR BRIDGES AND GENERAL BUILDING CONSTRUCTION

No. 2762 : 1956. Price 3s. This standard results from the growing need, principally in welded structural work, for mild steels whose "notch ductility" or resistance to "brittle fracture" is better than that of ordinary mild steel to B.S. 15. The foreword to the specification points out that as yet there is no general agreement about the correct tests to be applied to steel to measure these properties, but as far as the present knowledge goes, the Charpy "V" notch impact test, particularly if carried out at sub-atmospheric temperatures, provides some guidance.

The specification covers four grades of notch ductility, and each grade is covered in two tensile ranges, viz. 26/31 tons per square inch and 28/33 tons per square inch. The temperatures of impact testing for the first three grades are 0 deg. Cent., −15 deg. Cent. and −30 deg. Cent. respectively. For the fourth grade, the temperature of impact testing can be from −10 deg. Cent. to −50 deg. Cent. in 10 deg. steps, and, compared with the first three grades, the impact values required are higher.

The foreword also points out that although low temperatures are used for the impact tests, this does not necessarily imply that the steels described are guaranteed as being completely satisfactory for use at these temperatures, though in general they can be regarded as progressive improvements over ordinary mild steel in order of the grade numbers.

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

KARIBA DAM

SIR,—We have read the article, on page 110 of your issue of July 27, 1956, on the Kariba Dam, which suggests that the panel of British Consulting Engineers, of which Sir William Halcrow was the chairman, had recommended the construction of Kafue before Kariba, and that on Monsieur Coyne's advice this was reversed and priority given to Kariba. This is quite incorrect, as will be seen from the following extract from the panel's report of December, 1950.

"The information for Kafue Project is scanty and considerable further investigation is required before a definite proposal can be formulated. Nevertheless, we are of the opinion that, since on present information the capacity of the Kafue scheme is only 380MW at 70 per cent load factor, whilst the initial demand is 300MW and a rapid increase is forecast, Kafue would not be suitable as a first development. We recommend, therefore, that the Kariba scheme should be constructed first and that the Kafue scheme should be regarded as an extension to be carried out if and when required to meet the growing demand for power. In the meantime, the investigation necessary for a complete study of Kafue should be continued."

This recommendation was adopted by the Inter-Territorial Hydro-Electric Power Commission, but met with considerable disapproval by the Government of Northern Rhodesia, who favoured the Kafue scheme. The Northern Rhodesian Government then asked the panel to make a detailed investigation of Kafue. This was carried out and a report submitted in January, 1953, which was unanimously adopted by the Northern Rhodesia Legislative Council. The Government of Northern Rhodesia decided to proceed with the Kafue scheme but meanwhile Federation came about.

The Federal Government confirmed the construction of Kafue, but later there was much opposition to this in Southern Rhodesia. The Prime Minister, Sir Godfrey Huggins, now Lord Malvern, invited French engineers, including Monsieur Coyne, to give an independent opinion. Monsieur Coyne fully endorsed the recommendation of the panel that priority should be given to Kariba and the Federal Government decided on this course accordingly. Again, quoting from the Kariba report :—

"Various sites for the dam in Kariba Gorge have been considered and Site 3A at the lower end of the gorge has been provisionally selected. Some further investigation work is, however, required before the site can be finally fixed. The ultimate capacity of Kariba, Site 3A with top water level at 1644 R.L., is estimated at 1000MW at 70 per cent annual load factor. Should site 3A eventually prove unfavourable, Site 1 or 1A at the upper end of the gorge might be adopted, but the available output could be decreased thereby to 925MW."

Further borings at Site 3A indicated that while it was the most likely site at the lower end of the gorge, a dam could be more economically constructed at the head of the gorge at a site near 1A, which was referred to as Site X, and the panel recommended that the scheme should be modified accordingly. Monsieur Coyne again endorsed this opinion, and this site is the one which has been adopted. It will thus be seen that so far from the recommendation of the panel being reversed, they were fully endorsed by the recommendations of Monsieur Coyne.

SIR WILLIAM HALCROW AND PARTNERS
Westminster,
August 3rd.

[The English language is full of pitfalls for the unwary. We had no intention of suggesting that the Panel of British Consulting Engineers recommended the construction of Kafue before Kariba and that on Monsieur Coyne's advice this was reversed. But upon re-reading the article it is quite clear to us that, inadvertently, we did suggest it. Our apologies are due to Sir William Halcrow and to the Panel of British Consulting Engineers of which he was chairman.—ED. THE E.]

LONDON'S WATER SUPPLY

SIR,—The principal source of London's water supply is still the River Thames. From it the Metropolitan Water Board draws approximately 200 m.g.d. on the average. This amounts to 75 per cent of the summer flow. The remaining sources of water in the London area are already being utilised to the full.

Obviously London's demand for water is increasing. The system followed up to the present time has been to utilise to the fullest extent the summer flow of the Thames, the Lea, and deep wells, the balance being made good by withdrawals from reservoirs filled during the preceding winter. Further construction of reservoirs in the Thames Valley can only be carried out at the expense of large areas of valuable land.

Proposals have been made for pumping water from the middle reaches of the Severn. The Severn itself, however, is sometimes severely affected by drought conditions. Furthermore, withdrawals of water from the middle Severn would accentuate the pollution problems of the lower reaches.

I wish to bring forward a suggestion for substantially augmenting the summer flow of the Thames by pumping water from a hitherto untapped source.

At Christchurch the Hampshire Avon and the Stour discharge into the sea the following minimum summer quantities :—

	M.g.d.
Avon	100
Stour	50
	150

The water of these rivers, though hard, is crystal clear and famed for its purity.

By abstracting water from these two rivers at points very little above the limit of salt water, it would seem possible to take a high proportion of the total flow without adversely affecting the rivers proper.

I suggest that a pump station on the Avon, just below Christchurch Bridge, could withdraw 50 m.g.d. in the summer which would otherwise be lost in the estuary a few hundred yards downstream. It might well be found possible, without detriment, to withdraw as much as 100 m.g.d. from the combined rivers. This could be arranged by transferring a substantial proportion of the flow of the Stour into the Avon at a point above the pump station.

A high-pressure pipeline would convey the water from Christchurch to the Thames Valley. The nearest suitable waterway emptying into the Thames is the disused Kennet and Avon Canal in the Vale of Pewsey. The distance from Christchurch to the summit reach of this canal near Savernake Station is approximately 45 miles. An alignment can undoubtedly be found passing through open country. It would be an obvious advantage if the highest point of the line could be at or near its discharge into the canal, since this would enable the line to be kept filled when not in active use.

A 36in line is probably the largest all-welded high-pressure pipe which can be laid to-day using the conventional construction methods perfected by the oil and natural gas industries. Working at a hoop stress of 33,000 lb per square inch in $\frac{7}{16}$in by 36in cold expanded pipe of minimum yield 52,000 lb per square inch, a pumping pressure of 800 lb per square inch, at Christchurch would deliver 25 m.g.d. to Savernake with a power consumption of 12,000 h.p. approximately. Thinner walled pipe would naturally be adopted on the lower pressure sections. Thus, for 50 m.g.d. a double line with 24,000 h.p. would be required.

Considerable work would be necessary on the Kennet and Avon Canal between Savernake and Reading. Some reaches are fairly clear ; others contain heavy deposits of mud which it would be necessary to remove. Commercial navigation has long ceased on the canal and the locks are much decayed. It would be necessary to replace the existing lock gates by sluices, or fixed weirs. Since there would be no flood problem these control works could be simple.

Regarding costs : American published figures indicate that a 36in pipeline can be constructed in the States for approximately $160,000 per mile, which would involve £6,000,000 for the 45 miles of double pipeline. A diesel pumping station to handle 50 m.g.d. of raw river water at 800 lb per square inch with no stand-by units might perhaps be expected to cost around £3,000,000. The design of the pump station would be simple. Channels from the river with grids to prevent the entry of detritus and fish into the suction pond would seem sufficient in the way of headworks. Multistage centrifugal pumps in a sunken pump house would be used driven through step-up gearing.

A steam station using turbines directly coupled to centrifugal pumps would seem an attractive arrangement, but the problems

imposed by lengthy periods of disuse during the winter months are perhaps more serious in the case of steam plant than diesel.

An electric station drawing power from the mains would be a simple solution from the operating standpoint, but the supply of such a large consumer in a predominantly residential area might present more problems than it would solve.

For improvement works on the canal £1,000,000 might be allowed. Thus it would seem as a first approximation that for a capital expenditure of £10,000,000, the summer flow of the Thames could be increased by 50 m.g.d. (less losses), with the further prospect of increasing this volume to 100 m.g.d. at proportionate additional charges. No doubt losses would be incurred between Savernake and Shepperton. Nevertheless, it seems that a substantial augmentation of London's summer water supply could be assured in this manner.

Whatever might prove the cost of such a scheme it has certain attractions.

(1) It utilises water of the highest quality which at present flows unused into the English Channel.

(2) Little or no damage could be occasioned to the Avon and Stour by removing the greater part of the summer flow of those rivers from points immediately above the outfall into Christchurch Harbour.

(3) The land requirements of the scheme are insignificant. The area of the pump station would be small. The buried pipelines would not impair the use of the land for agricultural purposes.

(4) The quality of the water would be fully equal to that of the Thames.

(5) It once again brings into use the Kennet and Avon Canal, concerning the closure of which there has been much recent controversy.

(6) The construction cost seems comparable with that of a large new reservoir.

Once accepted, the principle of withdrawing a large volume of fresh water from the mouth of a river for pumping to a remote consuming area seems capable of extensive application. It is, as it were, a means of utilising the water a second time ; having run its course in its native river, it may be caught at the mouth for service elsewhere.

W. WHALLEY

Berks.
August 2nd.

Literature

Engineering Drawing and Geometry. By RANDOLPH P. HOELSCHER and CLIFFORD H. SPRINGER. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 64s.

ALTHOUGH it is generally agreed that the appearance of an engineering drawing may be ruined by bad lettering, not everyone will follow the authors of this book all the way in their opening statement that " The first essential to the use of the graphic language is a mastery of the art of lettering." Few will quarrel, however, with their remark that all engineers use either a vertical type or a slant type of lettering. The first chapter of the book contains many useful hints on lettering, both freehand and with mechanical guidance ; for good measure it gives alphabets in Old Roman type and in Very Old English type. It does not mention that for lettering small drawings a modern typewriter is quite useful. There are good hints on the use and care of instruments, including the motor-driven eraser, but the book, whilst warning the novice that the use of ink with drawing instruments has surprises and shocks in store for him, can naturally only hint at the extent and intensity of these irritations. The remark that a drawing may be given " life and vigour " by judicious use of the different line thicknesses recommended by the American Standards Association suggests more than average optimism. Certainly the technique is not widely employed in the many excellent drawings in the book itself. Early on is a short chapter on " geometric projections," but the subject is excellently developed in detail in later sections along with " Intersections and Developments," perhaps more familiar in Britain as " Interpenetration of Solids."

A short section on sketching is interesting, but seems incomplete in failing to mention squared paper as an aid. To those who from infancy have found no difficulty in drawing in one sweep a freehand straight line adequately true for sketching purposes, the instructions for sketching a straight line by overlapping strokes may be unnerving. Guidance is offered in freehand drawing of circles and ellipses, but when it is recommended that assistance in this operation may be obtained from a strip of paper acting as a trammel, it occurs to one that perhaps a ruler might be sanctioned as a help with straight lines. "Pictorial Sketching," "Axonometric Sketching," " Oblique Sketching," and " Perspective Sketching " are well treated, whereas a later chapter on " Perspective " is altogether terrifying in its thoroughness considering that its end products have no useful precision in the engineering sense. " Orthographic Projection " is well presented and its facilities and limitations will become firmly implanted in the mind of any student who successfully works out the problems contained in this chapter. The subject of " Sectional Views " is by its nature more closely controlled by arbitrary convention and in some places with no real necessity. Sanction seems to be given for moving (in imagination) some feature of a component (e.g. the spoke of a wheel) into a position where its projection is less difficult to draw. An alternative noted by the authors is to miss it out altogether. It might have been mentioned that where the shape of a component enjoins sectional views in different planes at unorthodox settings, a specific note explaining exactly which has been done in preparing the different views is preferable to the assumption that every reader of the drawing will agree with the draughtsman's interpretation of some obscure and rarely used convention.

There is a good section on " Dimensioning," but it does not stress that the ideal dimensioning of a drawing can be expected only from someone who knows in detail how the object will be made and measured. In the section " Fastenings," not all the definitions of dimensions of screws would be rigorous enough for a British Standard, and it is a little difficult to accept the reason given for the unsuitability of a V-thread for transmitting power. The section on " Shop Terms and Processes " is very useful, in that it lists a number of design features to be avoided because of the machining difficulties that they introduce. This should be valuable to draughtsmen who lack practical experience, but can hardly be a substitute for it. The subject of fixing machining tolerances is lightly handled under the heading " Drawings for Interchangeable Assembly," although a rational study of that subject might well fill a book in itself. There is a section on the layout of charts and diagrams and one on map drawing, from which one gathers that the representation of deciduous trees must not be undertaken lightly or wantonly and that palm trees must be upright.

" Architectural Drawing," " Structural Drawing " and " Pipe Drawing " have separate sections, while " Machine Drawing " is limited to pulleys, gears, cams and bearings. In " Tool Drawing " it is stated, rather mildly, that it is economical to use standard tools where they will perform satisfactorily. The further remark that " When they (i.e. standard tools) will not do the job required, special tools must be designed and made," may be classed as an obvious corollary. Nowhere does it appear to be sufficiently emphasised that design should be based on the use of standard tools and components ; perhaps it is desired to avoid any suggestion of pestering the draughtsman with pettifogging detail when so many alternative occupations are open to him.

In case these comments may suggest blemishes, it is emphasised that they apply to only a small fraction of a large volume. It is a book of direct practical utility, it is a valuable work of detailed reference, its printing and illustrations are of the highest quality, and its scope is much wider than its title may suggest. Its American origin nowhere obtrudes in the text and in no way diminishes its value to the British reader.

The Diecasting Process. By H. K. BARTON. London : Odhams Press, Ltd., 96, Long Acre, London, W.C.2. Price 21s.

ALTHOUGH diecastings are widely used in many branches of industry their actual manufacture is restricted to relatively few firms serving the general market, and to small plants in some works providing only for their own requirements. For this reason there are only a limited number of books dealing with the subject in a comprehensive manner, such as is required by students and others not fully familiar with the process. In this book the author has endeavoured, on the basis of his experience as a consultant, to give detailed and up-to-date information for the use of all engaged in making, buying and using diecastings. The subject matter is arranged in twelve main sections, dealing in detail with the basic requirements of the process ; diecastings ; dies ; machines ; fettling and machining operations ; surface finishes ; assembly and attachment methods ; production techniques ; designing for diecasting ; purchase of diecast components, and the diecasting plant. A large number of drawings and photographs are used to illustrate typical work and tools and many useful tables are included.

Books Received

Engineering Fluid Mechanics. By Charles Jaeger. Blackie and Son, Ltd., 17, Stanhope Street, Glasgow, C.4. Price 60s.

Iron and Steel To-Day. Second edition. By John Dearden. Oxford University Press, Amen House, Warwick Square, London, E.C.4. Price 12s. 6d.

Wireless Servicing Manual. Ninth edition. By W. T. Cocking. Iliffe and Sons, Ltd., Dorset House, Stamford Street, London, S.E.1. Price 17s. 6d.

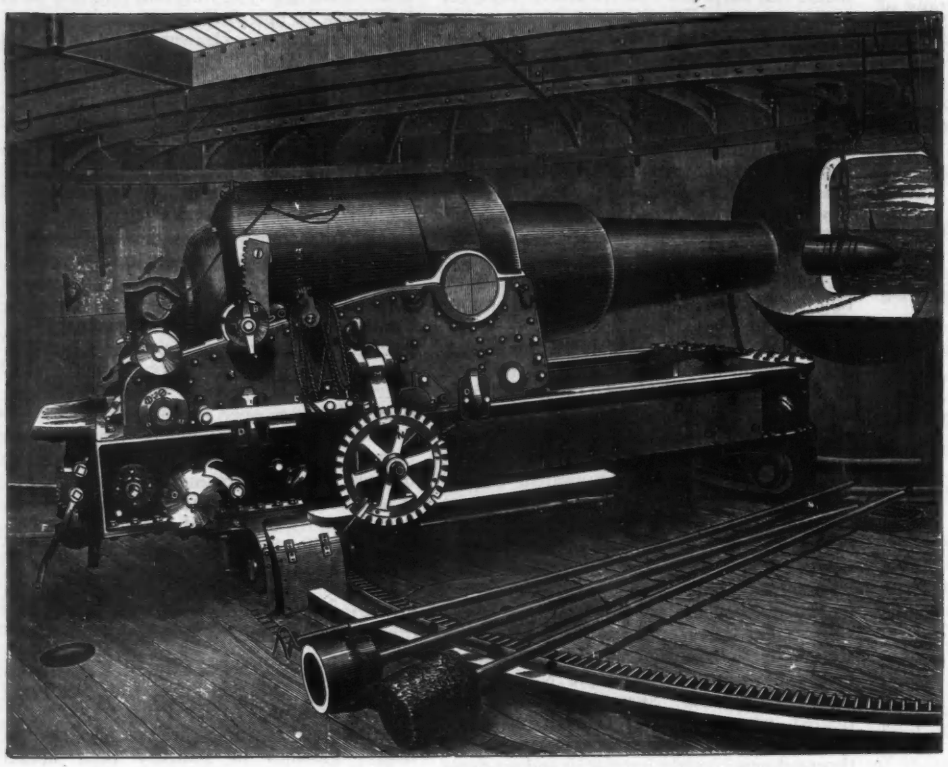
An Introduction to the Theory of Structures. By W. Merchant and A. Bolton. Blackie and Son, Ltd., 17, Stanhope Street, Glasgow, C.4. Price 30s.

Electricity in the Textile Industries. By W. E. Swale. George Newnes, Ltd., Tower House, Southampton Street, Strand, London, W.C.2. Price 30s.

The Economic Consequences of Automation. By Paul Einzig. Martin Secker and Warburg, Ltd., 7, John Street, Bloomsbury, London, W.C.1. Price 21s.

Progress in Semiconductors : Vol. I. Edited by A. F. Gibson, P. Aigrain and R. E. Burgess. George Newnes, Ltd., Tower House, Southampton Street, Strand, London, W.C.2. Price 50s.

ENGRAVINGS OF 1874



The upper of the two engravings on this page is reproduced from our issue of January 9, 1874, and provides an excellent impression of the kind of weapon being at that time mounted in British warships. We remarked of it that it was "a very carefully executed cut of the 12in gun of 25 tons, as mounted on board the Hotspur on a carriage of special construction, designed by Captain Scott for the Hotspur and likely to be adopted for the Temeraire and Superb."

The delightful imaginative picture below of a single-rail railway is possibly intended to depict the natural scenery of Turkey. For the particulars published in our issue of January 30, 1874, were received from Mr. J. L. Haddan, C.E., engineer-in-chief to the Imperial Ottoman Government, who recommended this method of constructing a railway as a means of overcoming difficulties of terrain in that country. The article states: "The permanent way of the Pioneer consists of a wall of a minimum height of 2ft 3in and 14in thick, surmounted by a single rail and sleeper, which simply consists of a 1¼in plank laid on edge in cement and tipped with thin half-round iron strips." As will be seen, locomotives and carriages were to straddle the rail. Of the engine the article says: "The locomotive is fitted on its underside with two pairs of horizontal wheels covered with leather which grip the wall. . . ." A screw and lever mechanism was to permit the grip on the wall to be varied to provide effective traction up heavy gradients.

Cunard Liner "Carinthia"

The "Carinthia," the third of four liners ordered by the Cunard Steam Ship Company, Ltd., for its Canadian service, has been completed recently. A total of 154 first class and 714 tourist class passengers are accommodated and there is space for 300,000 cubic feet of cargo. Two sets of double reduction geared turbines, taking steam at 550 lb per square inch gauge and 850 deg. Fah. from three water-tube boilers, develop 21,500 s.h.p. to give the ship a speed of about 20 knots.

THE "Carinthia," which is now sailing in the Canadian service of Cunard Steam Ship Company, Ltd., from Liverpool to Montreal, was named by Her Royal Highness Princess Margaret at the launching ceremony on December 14, 1955, and is the third of bear the name. The first "Carinthia" was a four-masted, twin-screw, cargo liner of 5598 tons gross, built and engined in 1895 by the London and Glasgow Shipbuilding and Engineering Company, and was lost five years later, by stranding on the coast of Haiti while on Government service during the Boer War. Vickers, Ltd., built the second "Carinthia," which was a twin-screw liner of 20,277 tons gross, at Barrow in 1925, and was sunk by a German submarine in 1940 while carrying out the duties of an armed merchant cruiser.

John Brown and Co. (Clydebank), Ltd., built and engined the new liner, which can be seen on trials in our illustration and which in outward appearance is a sister ship to the "Saxonia," described in our issues of September 17 and 24, 1954, and "Ivernia." There are nine decks, namely, sports, boat, promenade, main, "A," restaurant, "B," "C," and "D" decks, of which "A," restaurant and "B" decks are continuous, and "C" and "D" are partial forward and aft of the machinery spaces. Ten watertight bulkheads provide a two-compartment standard of sub-division, and the hull construction follows normal practice and has been built to the rules of Lloyd's Register of Shipping and the regulations of the Ministry of Transport.

Main Particulars

Length overall	608ft 3in
Length between perpendiculars	570ft
Breadth moulded	80ft
Depth moulded to "A" deck	46ft 3in
Draught loaded	28ft 1in
Cargo capacity	300,000 cubic feet
Gross tonnage	21,946
Service speed	19·75 knots

Accommodation

First class passengers	154
Tourist class passengers	714
Crew	461

Propelling Machinery

Type: Twin-screw, double reduction geared Parsons turbines
Normal power: 21,500 s.h.p. at 136 propeller r.p.m.
Astern power: 60 per cent of ahead power
Boilers: Three Foster Wheeler
Steam pressure: 550 lb per square inch gauge at superheater outlet

Electrical Machinery

Type of generators: Four W. H. Allen turbo-generators
Rating: 750kW, 225V d.c.
Emergency: Two diesel-driven generators
Rating: 75kW

Accommodation

Single and double-berth cabins are provided for the 154 first class passengers on the main deck, and each room has a bath or shower. A variety of distinctive decoration schemes, embodying a number of veneers, have been adopted, and there are port and starboard three-room suites consisting of bedroom, sitting room and dining room, which can be used as individual rooms if required. Set high in the ship is the sports deck lounge, which has teak furniture and is available as a dancing space, while the remaining public rooms are on the promenade deck with glass-enclosed promenades to port and starboard. Forward is the smoke room with its cocktail bar, oak-panelled walls, mullioned windows and hide-covered doors. An adaptation of Jordaen's "Le Roi Boit" is in the cocktail bar, while to port is a chimney breast with a design reminiscent of Tudor brickwork.

Aft of the smoke room is a wide entrance and side passageways, with a library, having green as the main decorative colour, to port and a shop to starboard, leading to the lounge. This room is decorated in Regency style, with peach-coloured glass far lights set above panels, and including an eighteenth-century clock, paintings of Canadian singing birds and painted roundels of classical and pastoral scenes. There is a small oval dance floor and a raised orchestral platform. Further aft to port is the small intimate drawing room, again reflecting the Regency period. A rococo style lends elegance to the restaurant, which can seat 122 at tables for two, four or six, which is panelled in grey sycamore veneer. Engraved mirrors are set in panels and the main decoration is a mural painting representing "Dinner at Versailles." The cinema extends through three decks and is equipped with a wide screen and is used by both classes of passengers, there being a balcony entrance on the promenade deck for the first class passengers and a stalls entrance on the main deck for the tourist passengers.

State rooms, having two or four berths, for the 714 tourist passengers, are located on the main, "A," restaurant and "B" decks. The smoke room and cocktail bar is aft and the boat deck is lined with small alternately raised and sunken oak panels surmounted by a plaster frieze depicting the life of the beaver. Two painted murals have as their subject the early French settlers.

On the promenade deck there are enclosed spaces to port and starboard and a spacious lounge, panelled in white Canadian pine, transparent plastic covered, which has a large dancing space and band platform. At the aft end of the house is a library, which closely resembles its first class counterpart, while at the forward end, to port, is the drawing room, decorated in Adam style, and to starboard is the soda fountain. Nearly 500 passengers can be seated at tables for two, four or six in the restaurant, which extends for the full width of the ship and is decorated in Pompeian style with characteristic colourings, the frieze having as subjects fabulous animals, gods and goddesses. Some of the public rooms are illustrated in the photographs which we reproduce here.

Colonial style has been adopted for the staircases and entrances, those for the first class being veneered in white sycamore and those for the tourist being white enamelled. The first class stairway extends down from the sports deck to restaurant deck, and there is also a lift which serves the decks between the boat and restaurant decks. In the tourist accommodation there are two main staircases, the forward one connecting "B," restaurant and "A" decks, and aft one rising from "B" deck to the promenade deck. At the latter stairway, and serving the same decks, are two lifts. Both classes are well provided with open deck spaces for walking and for sporting activities.

A suite of rooms is provided for the captain immediately below the navigating bridge, and the quarters for deck and engineer officers are on the boat deck. Particular attention has been

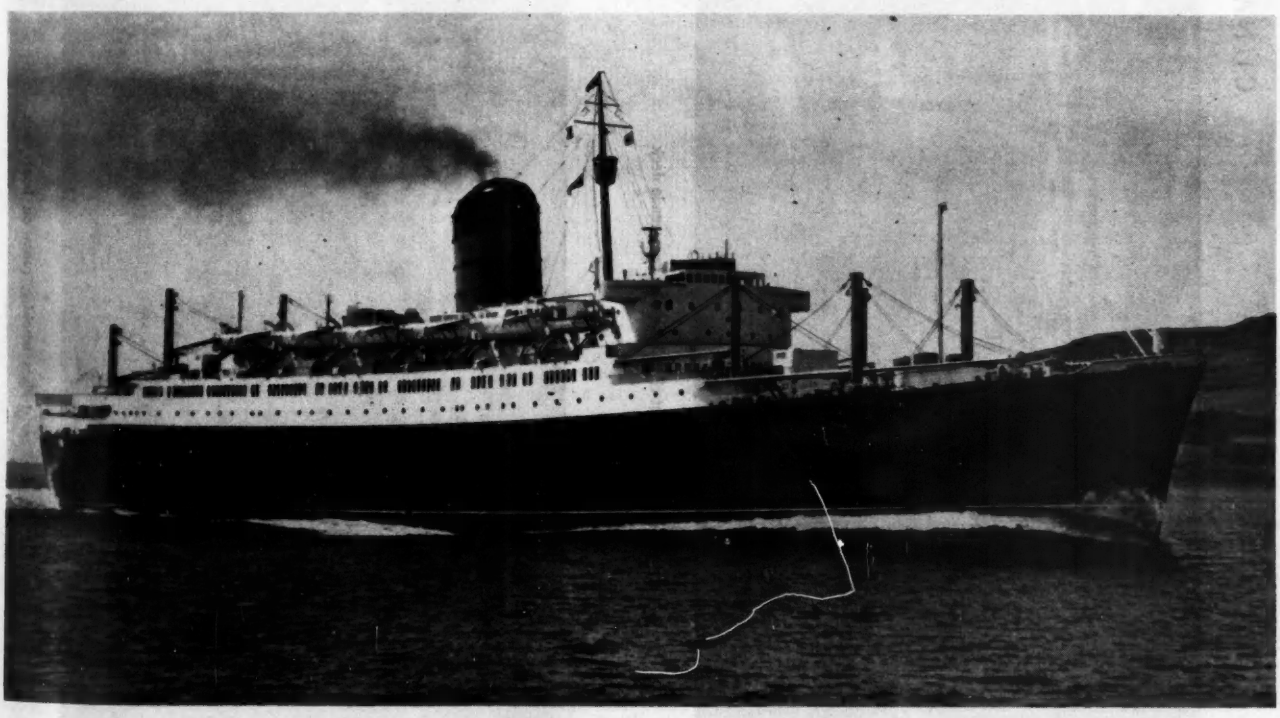


Fig. 1—Cunard liner "Carinthia" on trials. The gross tonnage is 20,277 tons and there is accommodation for 154 first class passengers and 714 tourist class. The cargo space amounts to 300,000 cubic feet

CUNARD LINER "CARINTHIA"

Fig. 3—Ship's cinema for first class and tourist passengers

Fig. 5—Tourist restaurant with accommodation for nearly 500 passengers

Fig. 2—First class lounge on promenade deck

Fig. 4—Tourist class smoking room on boat deck

paid to the crew's accommodation, for whom roomy sleeping quarters and spacious recreation rooms have been arranged. For interior decoration besides the use of veneers, modern materials such as "Warerite," "Perspex," plasticised cloth and "Terylene" have been extensively employed.

Auxiliary Equipment

Thermotank, Ltd., has been responsible for the air-conditioning and ventilation systems throughout the ship, in which all the accommodation for the passengers and crew, public rooms, restaurants, cinema, hospitals and shopping centres, is air conditioned. The well-equipped galley and various service rooms are located between the two restaurants and illuminated by a.c. fluorescent tube fittings, while all the power-driven units are operated from an a.c. supply. A supply of good drinking water is provided by a 70 tons per hour purification plant of Sutcliffe Speakman manufacture. All three passenger lifts, which have centre opening doors and are veneered in bleached sycamore, have been supplied by J. and E. Hall, Ltd., as have the three stores lifts, a baggage lift, a lift to serve the engineer officers, and the refrigerating machinery.

Five holds, two forward and three aft of the machinery spaces, carry the cargo and are served by two 10-ton and twelve 5-ton derricks operated by two 5-ton and twelve 3-ton electric winches provided by Laurence, Scott and Electromotors, Ltd. The same company manufactured the two 1½-ton gangway winches, while Clarke, Chapman and Co., Ltd., supplied the forward electric windlass, for handling the 8-ton bower anchors and 3in "Tayco" stud link chain cable, and the aft windlass for handling the 5-ton stream anchor and 2⅞in "Tayco" cable. There are also two electric warping capstans, each with a pull of 15 tons, and a 15-ton worm and spur geared warping winch powered with a 85 b.h.p. motor. Steering is effected by gear manufactured by Brown Brothers and Co., Ltd., and the company has installed its stabilising equipment, each fin having an outreach of 12ft and a fore-and-aft length of 6½ft. Spaced throughout the ship below the water line are five sewage disposal plants built by Adams Hydraulics, Ltd.

The watertight bulkheads are fitted as required with watertight doors, of which there are eighteen constructed by Donkin and Co., Ltd. Fire protection is afforded by a Grinnell automatic sprinkler installation, which is divided into twenty-one sections, fireproof divisions and fire-resisting doors, and by the extensive use of "Marinite" incombustible sheet. For the cargo holds, for the ventilation of which Woods of Colchester, Ltd., has provided ten 24in fans of 3500 cubic feet per minute capacity, there is a Walter Kidde carbon dioxide fire-extinguishing system, while the boiler-room has a carbon dioxide total flood system. Welin-Maclachlan overhead gravity davits carry the complement of twelve aluminium alloy lifeboats, consisting of two 36ft motor lifeboats, each of 136 persons capacity; eight 36ft hand-propelled lifeboats, each accommodating 146 persons, and two 26ft emergency boats, each capable of taking 43 persons.

For internal communication purposes between departments a "Strowger" private automatic telephone exchange, euipped with sixty lines, has been installed by Communication Systems, Ltd. For navigating the ship there are a Sperry Mark XIV gyro-compass, repeater compasses and gyro pilot; Siemens electric telegraphs; compasses, &c., by Kelvin and Hughes (Marine), Ltd.; Decca navigator, and an extensive radio equipment installed by the International Marine Radio Company, Ltd.

Main Propelling Machinery

The propelling machinery for the ship, which is in charge of the chief engineer, Mr. F. O. Summerfield, D.C.M., is in most respects identical with that installed in the "Saxonia" and "Ivernia," except for the boiler plant. There are two independent sets of machinery, consisting of h.p. and l.p. turbines, which drive, through double reduction double helical gearing, four-bladed manganese bronze propellers of Scimitar design, and 17ft 3in diameter, manufactured by the Manganese Bronze and Brass Company, Ltd. A total normal ahead power of 21,500 s.h.p. is developed at 136 propeller r.p.m., and a maximum of 24,500 s.h.p. at 144 propeller r.p.m., while 60 per cent of the normal ahead is developed by the astern turbines. The h.p. astern turbine, consisting of a two-row impulse wheel, is overhung from the forward bearing of the h.p. ahead turbine, which is of all-impulse design and runs at 4025 r.p.m. The same outer casing houses the double-flow, all-reaction, l.p. ahead turbine, which runs at 3700 r.p.m., and the two-row impulse l.p. astern turbine. The motor and turbine-driven pumps for circulating lubricating oil to the turbines and gearing were manufactured by Mirrlees (Engineers), Ltd., and the system includes Serck coolers and oil vapour extractors and Alfa Laval purifiers.

In common with her sister ships, "Saxonia," and "Ivernia," the "Carinthia" is equipped with the Weir double deaeration closed feed system. The condensers, one for each set of engines, each have a cooling surface of 11,000 square feet and maintain a 29in vacuum with circulating water at 60 deg. Fah. One working and one standby extraction pump serves each condenser and each can withdraw 78,000/170,000 lb per hour of condensate and discharge through air ejectors, glands steam condensers and deaerator to the feed pump suction. The centrifugal main feed pump operates at 3000 r.p.m. and can discharge 213,000/277,000 lb per hour against a pressure of 775 lb per square inch gauge. As standby there is a three-stage, turbine-driven pump of the same capacity and for harbour duties there is a similar pump arrangement, but the capacity is 50,000/65,000 lb per hour. Make-up feed is provided by a double distillation plant with two vertical evaporators, each producing 60 tons of vapour per day.

As noted already, the major difference between the "Carinthia" and her sister ships now in service is in the steam-raising plant. The earlier ships were equipped with four end-fired, three-drum Yarrow water-tube boilers, whereas the "Carinthia" has three Foster Wheeler E.S.D. boilers, each fitted with a superheater, bled steam air heater, air attemperator and a Forster marine economiser manufactured by E. Green and Son, Ltd. Fig. 7 gives a general view of the stokehold and the line drawing (Fig. 6) shows the general arrangement of the boilers,

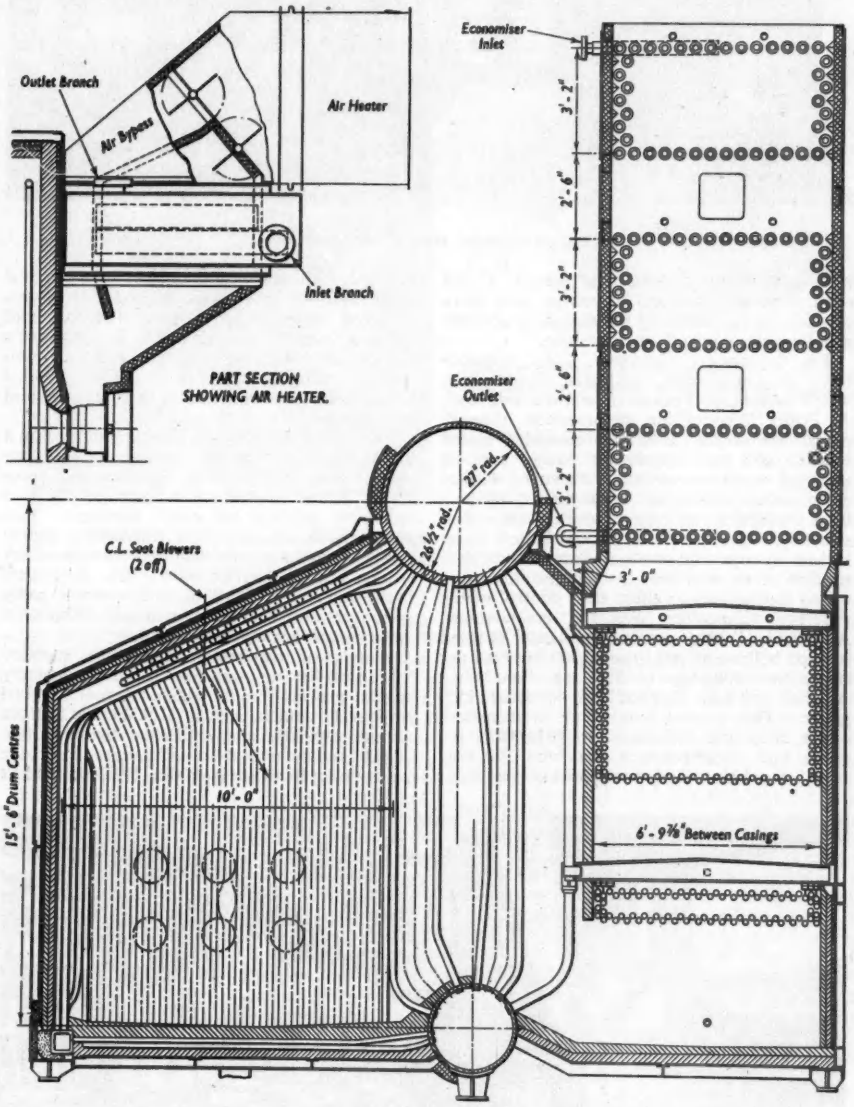


Fig. 6—General arrangement of E.D.S. boiler

each of which has an output of 65,000 lb per hour at normal load and 97,500 lb per hour at maximum design load, and supplies steam at 550 lb per square inch gauge and 850 deg. Fah. at the superheater outlet. Each boiler is designed with a total generating surface of 14,990 square feet and a superheating surface of 3470 square feet. The arrangement of boiler and superheater, which is located after the main generating tube bank, is designed to limit the gas temperatures to the superheater elements in order to reduce the temperature of the tube metal and to avoid the problems of slagging, and support plate corrosion, usually associated with

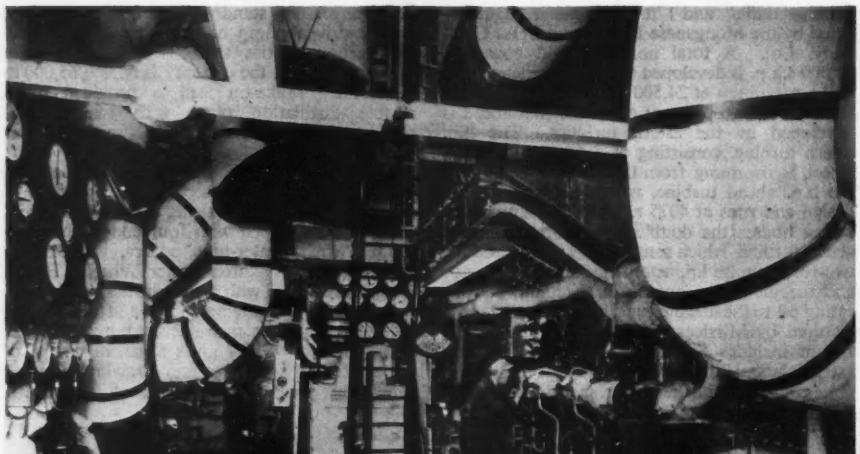


Fig. 7—General view of stokehold

high-temperature superheaters placed a few rows from the furnace. Inspection and maintenance are facilitated by the design, which also simplifies cleaning and water washing.

The Superheater Company, Ltd., manufactured the multi-loop, two-pass superheaters, which have support beams of heat-resisting steel. A Foster Wheeler air attemperator, through which the steam flows continuously, placed between the two superheater passes, controls the final steam temperature. Extruded surface gilled tubes within the attemperator give a large reduction in steam temperature when swept by the full air weight and simple interlocked by-pass and shut-off dampers regulate the flow of air on its way through the attemperator to the burners to effect close control of the superheat temperature over the service range. A "Weldex" bled steam air preheater is fitted to each boiler and will raise 80,500 lb of air per hour from 100 deg. to 225 deg. Fah. when supplied with bled steam at 29 lb per square inch gauge. This normal flow of air is increased, under maximum conditions, to 103,000 lb per hour, with a temperature rise from 100 deg. to 221 deg. Fah. Clyde soot-blowing equipment is fitted, with Sturtevant vacuum soot removal plant, and the boilers operate under Howden's balanced closed trunk system of forced and induced draught. In each uptake is a Howden's dry pattern vortex dust collector and a Gordon desuperheating system is fitted. Oil is supplied to the boilers by Wallsend oil fuel pumping and heating plant.

The electrical generating plant is mounted on a flat at the aft end of the engine-room and consists of four 750kW, 225V, self-contained generators driven at 800 r.p.m. through 10 to 1 reduction gearing by steam turbines. Two 25kVA, three-phase motor alternators supply power for fluorescent lighting in machinery spaces, kitchens, public rooms, &c. Elsewhere in the ship are two 75kW diesel-driven emergency generators and a nickel iron battery. The main switchboards are shown in Fig. 8.

Woods of Colchester, Ltd., has supplied "Maxcess" ventilating fans for the machinery spaces, and air for the engine-room is supplied by four 48in units, each of 37,000 cubic feet per minute capacity, and exhausted by two 38in, 20,000 cubic feet per minute units. For the boiler-room there are two 30in, 10,000 cubic feet per minute supply fans and three 38in exhaust fans of 25,000 cubic feet per minute capacity, while for the screen casing there are four 4000 cubic feet per minute units. Two 24in exhaust fans of 5000 cubic feet per minute serve the generator flat.

Fig. 8—Main switchboard

British and German Export Competition

THE *Board of Trade Journal* has published a long article on the impact of German competition as it appeared in the early part of 1956. The Engineering Advisory Council considered the report, which has particular reference to the engineering industry, and decided that it should be widely publicised as a fair and important statement of the facts. The council recommended that the report should also be discussed jointly by both workers and managements in factories and by local productivity committees. It is stated that perhaps the most significant feature of the analysis of costs and of the specific factors affecting Germany's exports is the evidence that labour costs per unit of output in the metal using industries have remained fairly constant since 1950 in Germany, whereas in this country they have risen by as much as a quarter. There is no reliable evidence as to comparative productivity in this country and Germany. But whatever the present position on productivity might be, states the report, it is clear that the trend of labour costs over the last five years has been in the favour of Germany, and this can be fully explained by her very rapid increase in productivity. Wages have risen at about the same rate in the two countries, but German productivity has risen much faster than that in the United Kingdom.

It is interesting to note that, contrary to popular assertions, so far as government policies are concerned, German exporters gain little, if anything, from more favourable treatment than that accorded to exporters in this country. This is considered particularly true since the abolition of the taxation export incentives at the end of last year. No attempt is made in the report to compare the performance of the two countries in the general field of sales promotion. Nevertheless, there is no doubt that the German sales effort in overseas markets has been exceptionally vigorous, being stimulated by the single-minded determination of employers and workers alike to rebuild and restore Germany's power and prestige abroad after the period of collapse which followed defeat in the war. United Kingdom export efforts, on the other hand, have been weakened by the competing attractions of a buoyant home market, which has made domestic sales so easy for the manufacturer that he has had less incentive to sell his goods abroad.

In conclusion, the report states that an examination of the prospects for the future does not suggest that there will be any early or significant change in the present relationship between costs and production in the two countries. If, therefore, the challenge of German competition is to be successfully met, British industry must pay special attention to improving its sales promotion abroad, and it must not neglect any opportunities of obtaining new export business. At the same time more must be invested in the modernisation and expansion of industrial capacity in this country. In the long run a competitive advantage will rest with the country which is the most successful in preventing inflation, and which achieves the most rapid increase in efficiency and sales promotion, and advances in technology.

SELF-ADHESIVE SEAL.—Polyurethane foam in strips backed with adhesive is now being supplied in various thicknesses and widths by Sealdraught, Ltd., Chandos House, Buckingham Gate, S.W.1; if required, cross-sections ¼in by 19in can be provided. Besides acting as a seal, particularly to prevent dust reaching the highly charged face of a cathode-ray tube, it also serves to isolate vibration. Thermometers or other glass components are readily mounted on the foamed plastic. In use it is not affected by water, oil, oxygen, light, bacteria or insects, although the adhesive may be attacked by some solvents. The strip adheres to most clean surfaces, and is supplied with a protective backing on the adhesive face.

Ramjet Engine

AN aerothermodynamic duct for missile propulsion has now been successfully developed by Bristol Aero-Engines, Ltd., and named "Thor."

The engine, a front view of which appears as Fig. 1, is an example of the very simple supersonic ramjet designed for one flight speed. The air intake has a fixed central body, from which an attached shock springs across to the sharply chamfered outer edge of the annulus. A second shock wave stands on this edge and stretches across the inlet to meet the nose cone at a right angle, and the air passing through these two fronts enters the subsonic diffuser and passes the fuel sprayers. Downstream of the centre body there is a flame holder, and the greater part of the length of the engine is a completely hollow combustion space. At the rear end of the duct a small contraction is provided for the final exhaust nozzle : this contraction is defined by a steel ring inserted into the main shell and welded at its leading edge. The nozzle is cooled by admitting air to the toroidal space outside it, the air then passing out through a narrow annular gap between nozzle and shell.

The engine is devoid of controls and other ancillaries, being intended, presumably, for missiles of limited range flying within the atmosphere. (A ramjet surface-to-air missile, the "Talos" has been developed, and may be adopted, for defence roles in the U.S.A.) The engine is supported on a strut or pylon close to the front of the duct, and there is another bracket near the nozzle. Fig. 2 shows a view of the engine from the nose of a vehicle : after the fuel was consumed, the vehicle was shattered by an explosive charge, and returned to earth slowly enough for the cine-camera to be recovered. It appears that there are eighteen main fuel jets beside the spray of fuel from the front of the nose cone. The three struts supporting the centre body can be seen clearly. The engine is lit up very simply by a set of pyrotechnic flares which are ignited before the solid propellant boosters accelerate the craft off the ground. Fuel injection is then commenced, and it is claimed that 100 per cent success in starting has been achieved.

The film was impressive by reason of the extreme steadiness of the picture, suggesting that the high levels of vibration associated with rocket motors, which have such a severe influence upon the design of electronic and similar components, were not found in the air-breathing plant. No figures of performance have been disclosed, but an engine of the same size, according to the makers, could give at least 15,000 lb thrust at Mach 3. The engine is in use on at least one production missile.

Fig. 1—The "Thor" ramjet engine : the air intake is blanked off. The ring of holes around the rear of the engine admit air to cool the throat of the nozzle

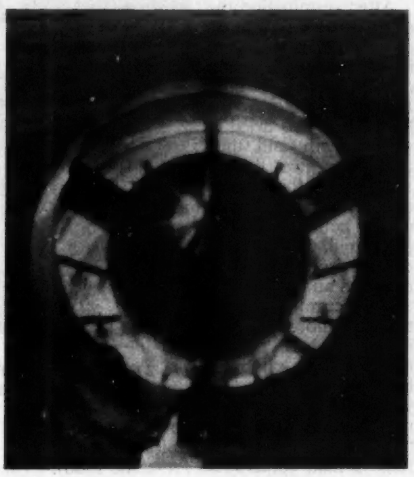


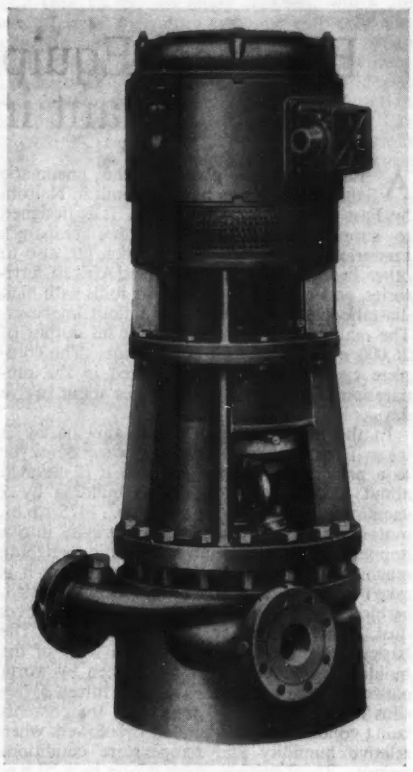
Fig. 2—Ramjet in flight over the Woomera range. The streaks on the nose cone are made by fuel fed from holes near the tip

The makers, and previously the Bristol Aeroplane Company, Ltd., have been working on ramjet propulsion for over six years now : one of their test vehicles was illustrated on page 51, January 9, 1953. An agreement sharing research results between Bristol and Boeing in the U.S.A. contributed to the "Thor." Test facilities for athodyds have been built by Bristol, and to provide the vast quantities of high energy air required for short periods, a plant has been built in which energy is stored in the form of steam under pressure in large lagged drums. Research work has been done on variable geometry air intakes, such as would be required for aircraft flying at varying Mach numbers.

High-Temperature Circulating Pumps

HIGH-TEMPERATURE water circulating pumps of horizontal construction for static pressures up to 150 lb per square inch have been made for some years by Rhodes, Brydon and Youatt, Ltd., Gorsey Mount Street, Stockport, and this firm is now manufacturing a new range of vertical pumps for pressures up to 350 lb per square inch. The new pumps, as were the previous models, are directly connected to their driving motors, and a typical pump for marine or industrial service is illustrated on this page.

In the cast steel pump casing the suction and delivery branches are set in line at a common centre height and offset from the axis of rotation. A force-fit neck ring fitted in the casing is also made of steel to avoid differential expansion troubles. A conventional single-entry, double-shrouded impeller, keyed to the driving shaft, is located axially by a cap nut. The pump cover



Motor-driven vertical high-temperature water circulation pump for pressures up to 350 lb per square inch

is formed by a cast iron stuffing-box plate, which also incorporates cooling water inlet and outlet connections and a drain connection. A gunmetal stuffing-box has fins machined on its outer surface to increase the area of contact with the cooling water, and in it provision is made for four rings of packing. Below the stuffing-box proper is fitted a long throttle bush with a very fine clearance on the shaft sleeve. This bush is designed to provide a means of pressure breakdown and ensure that the leakage water is cooled as it passes in a thin film along the annular clearance. The method of cooling leakage water is designed to reduce the tendency to vaporise on contact with the atmosphere, and to assist the packing by providing a "barrier" of higher viscosity liquid to keep back the low-viscosity water in the pump casing.

The shaft sleeves are made of phosphor-bronze, that at the bottom being vented by a hole to relieve any tendency for an internal pressure to build up when heated. A conical portion is turned on the upper sleeve to deflect any splashes of leakage water from the bearing housing. This taper also provides a locking means by which the gland can be held up when the stuffing-box is being repacked. At its lower end the shaft is supported in a roller bearing in a housing with a cooling water jacket. This lower bearing takes radial shaft loads, whilst a duplex ball race on the upper bearing assembly withstands axial loading of the shaft due to hydraulic conditions and the weight of the rotating parts.

BY-PASS ROAD AT BORROWASH, EAST MIDLANDS.—We are informed by the Ministry of Transport and Civil Aviation that to relieve congestion on the Nottingham-Derby Trunk Road, A.52, where it passes through the village of Borrowash, work is to start during the second week of August on the construction of a by-pass, 2¼ miles long, with twin carriageways, each 24ft wide. The scheme is expected to cost £255,000. Connection with the existing trunk road at the western end will be made with a roundabout. At the eastern end, where a temporary junction is to be formed, it is intended ultimately to build a fly-over and continue the by-pass eastwards to link up with the proposed Sandiacre and Stapleford by-pass. The scheme has been designed by Mr. S. Mehew, county surveyor, Derbyshire County Council. The contract for the works has been awarded to Messrs. Gee, Walker and Slater, Ltd.

Electrical Equipment for Malting Plant in Nairobi

A NEW malting plant of the pneumatic Saladin-box design has been built in Nairobi by East African Breweries, Ltd. It is designed to supply malt not only to the company's breweries in Kenya and Tanganyika, but also to other breweries in the three East African territories, and to provide local flour mills with high diastatic malt for use as a wheat flour improver. The malting plant is designed for an output of 26,000 quarters of malt per annum. The complete cycle of operations involved in the preparation of malt from barley takes about twelve days.

In the new maltings (Fig. 1) raw barley is taken from the barley intake by worm conveyor to a pneumatic pipeline in which it is elevated about 120ft to the top of the building by a vacuum pump driven by a 45 h.p., 1475 r.p.m. motor. It is then discharged by gravity into a hopper and through an automatic weighing machine. From the bottom of the hopper it is taken through a precleaning machine which, by blowing air through the barley grains, removes dust, straw and other foreign particles. The barley is then raised to the eighth floor of the building by bucket elevator and then by worm conveyor to barley silos. There are fifteen barley silos in all, holding 250 tons each, the contents being conditioned and aerated by blowers when relative humidity and temperature conditions permit. Three blowers, each driven by a 40 h.p. 2955 r.p.m. motor, supply the air to these fifteen silos.

When the barley is required for malting, it is conveyed pneumatically, the pump being driven by a 45 h.p., 1475 r.p.m. motor to the final cleaning hopper, and then by gravity through screens and aspirators, where half-corns, seeds, &c., are removed and the barley is sorted into two grades. The first and second grade barley is fed by gravity to steeping hoppers.

The barley is next steeped in water at 54 deg. Fah. for approximately thirty-five hours, during which time the water is changed four times and the barley is aerated by transfer to other steep tanks. From the steeps it is taken to one of eight malting boxes, each holding 16 tons 10 cwt, where it is allowed to germinate for approximately eight days. The boxes are continually aerated at a temperature of 54 deg. to 60 deg. Fah., the humidity of the aeration being controlled by fans and water sprays to each malting box. Temperatures of the steep water and the aeration spray water for the germination boxes are controlled by two ammonia compressors supplied by Messrs. J. and E. Hall, Ltd., and installed in the engine house. They are driven by 90 h.p., 1000 r.p.m. synchronous induction motors operating at unity power factor.

After germination the product, known as green malt, is conveyed by pneumatic pump driven by a 55 h.p., 1465 r.p.m. motor, to the kiln, where it is dried to stop growth and then cured to give flavour and colour, the process taking from eighteen to twenty hours. The kiln is oil-fired, the temperature being controlled and recorded automatically.

When curing is finished the kiln floor is tilted in two halves, putting the malt to hoppers beneath the kiln. A worm conveyor then carries the malt to another controlling hopper and then to a screening and aspirating machine, to remove malt culms (sold for cattle food). The deculmed malt is next put over a gravity-shaker machine to remove any ungerminated or broken corns, and the dressed 100 per cent malt is taken by bucket elevator and worm conveyor to the top floor of the building, to be stored in one of six malt silos. When the malt is required it is blended automatically by drawing off from any of the six silos in the proportions necessary to obtain a mix with the desired characteristics, and is finally carried by worm conveyor through automatic weighing machines for packing into plastic bags and sacks before despatch to the various breweries owned by the company and other customers. Plastic bags are used to prevent moisture absorption, which would make the malt "slack"; malt normally contains only 2 to 3 per cent of moisture. The plant runs continuously, seven days a week, under constant supervision, since a slight variation in the temperature of the malting boxes, the steeping water, or the kilning and curing, would ruin the product.

The incoming supply to the maltings is taken through an oil circuit breaker and then to an English Electric combination fuse switchboard for control of the lighting and motor supplies through sub-distribution boards located throughout the maltings; the motors are supplied at 415V, three phase, 50 c/s. In all sixty-one English Electric motors, with outputs from ¼ h.p. up to 90 h.p., are installed. Where dust is present in the atmosphere, the motors are totally-enclosed, fan-cooled or closed-air-circuit machines (Fig. 2), open protected motors being supplied elsewhere.

This electrical plant was made by the English Electric Company, Ltd., the electrical drives being supplied through George Adlam and Sons, Ltd., of Bristol and the distribution equipment through the electrical contractor, The Berkeley Electrical Engineering Company, Ltd.

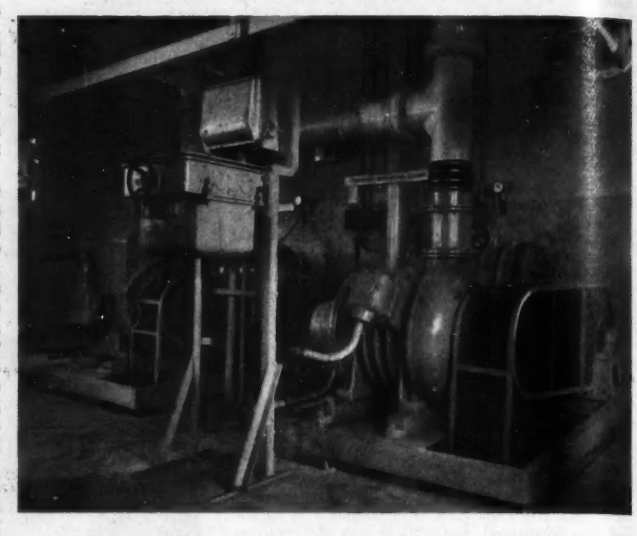


Fig. 2—Vacuum pumps for barley and green malt in the East African Breweries maltings, Nairobi, driven by totally-enclosed 45 h.p. and 55 h.p. motors

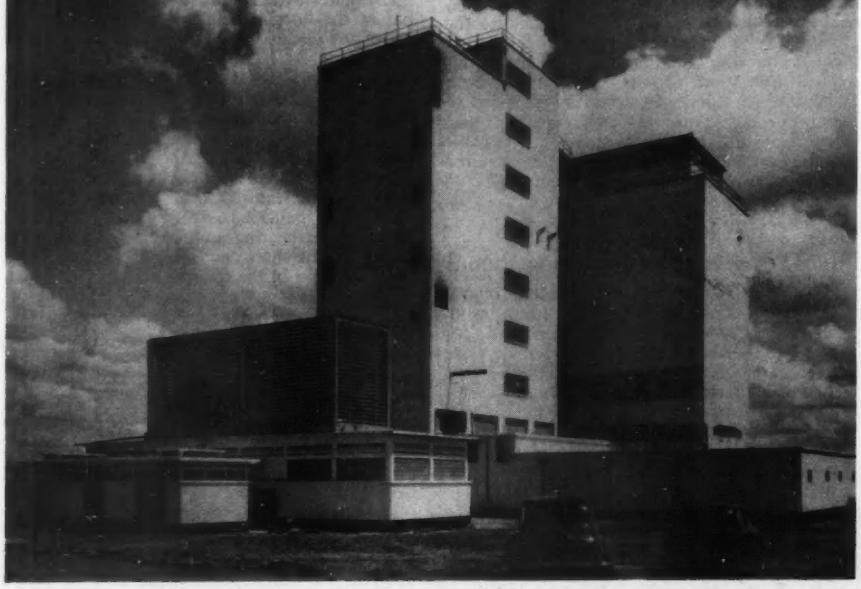


Fig. 1—The new malting plant of East African Breweries, Ltd., at Nairobi, is designed for an annual output of about 26,000 quarters, working on a twelve-day cycle of operations

Royal Naval Surveying Service

BY OUR NAVAL CORRESPONDENT

AMONG the lesser-known, but more useful, activities of the Royal Navy in peacetime is the surveying and charting of distant seas and coastal areas used by ships of all nations. Apart from employing three ships and five 50-ton motor launches on surveying the coasts of the British Isles, the Royal Navy maintains four vessels constantly on foreign service—in the Mediterranean and Persian Gulf, and on the coasts of East Africa, West Indies, Borneo and Malaya. Only one of these seven ships was specially built as a surveying vessel—H.M.S. "Vidal," of 2173 tons, the first prefabricated, all-welded ship to be built in a Royal Dockyard. Completed in 1954, she is diesel-electrically driven, fitted with air conditioning in all living and working spaces, and was the first naval vessel to be equipped with a heat exchanger system. She has a flight deck and hangar with a helicopter and is equipped with a complete self-contained printing unit capable of producing lithographic plates and printing full-sized Admiralty charts. Of the remaining six vessels, four are 19·5-knot, 1640-ton frigates laid down in 1944 and completed five years later; the other two are 17-knot ocean minesweepers of 830 tons, built before the war. With the exception of the saluting guns carried

in the five larger ships, they have no armament of any kind, but all are suitably stiffened to mount a defensive armament in the event of war. With their asdic sets, two of which are installed in each ship for locating wrecks, small shoals and pinnacle rocks, they should prove very useful on patrol in preventing submarines rising to the surface and firing guided missiles against shore targets.

The surveying year is divided into two periods, the "season" lasting thirty-six weeks and the "lie-up" (during the bad weather season) of sixteen weeks when the fair chart of each area surveyed is drawn and checked, and all data connected with the surveys written up in the final form for record purposes. One of the principal tools of the hydrographic surveyor is the echo-sounding installation which has for long superseded the lead and line for obtaining soundings, except in very large-scale harbour work. The lead and line are, however, still used for checking and aligning echo-sounding sets and for proving or disproving spurious or suspect echoes. It is indeed regrettable that more use is not made of this method when new shoals are reported from outside sources. Much time and labour are wasted by surveying vessels in disproving or checking dangers reported on the strength of an echo-sounding indication only. Many of them are found to be non-existent and caused by an incorrect use of the echo-sounding machine. The sets used in surveying vessels range from the portable or boats' sets capable of operating in about 300 fathoms, to the ship's set. The latter operates in conjunction with the asdic installation, and can obtain an audible though not necessarily recordable sounding in the greatest known depths. Up to date the greatest depth recorded is 5940 fathoms (nearly 6 nautical miles, obtained by H.M.S. "Challenger," a surveying ship recently scrapped, from a sounding in the Marianas Trench (Lat. 11° N, Long. 142° E.).

Radar is now also extensively employed in surveying work for scales smaller than 1/50,000, which require ±15 yards accuracy at 40,000 yards. The advantages of using radar are that only about half as many floating beacons are required as for visual fixing and the work can proceed in bad visibility or at night, when visual methods would not be possible. Radar is also useful for small-scale searches on passage when a single beacon can be laid in the vicinity of a reported danger and a rapid preliminary survey carried out using radar distances with either radar or visual bearings. Its main disadvantage is the difficulty in finding suitable shore marks which can be clearly distinguished from general land echoes and which will present a good target from any direction. Ideal radar marks are very sharp headlines or islets lying offshore, but these are few and far between. Visual fixing, on the other hand, requires only a spire, flagstaff, house or even merely a conspicuous bush or rock. Artificial targets for radar can be made from a series of hollow inverted pyramids, a strong reflected signal being received no matter from which direction the radar beam arrives. Special lightweight octohedral reflectors have been designed which can be clamped to a spar and are effective at ranges up to about 8 miles. They cannot, however, be identified if erected ashore and are usually secured to floating beacons or set up on offshore patches of rocks and sandbanks.

All ships and motor launches in home waters are fitted with navigational "Decca" equipment for conning ships and sounding boats (which can also carry this equipment when required) along straight lines while sounding, the fixing being done visually in the normal way. A development of this installation is the "Two-Range Decca" system, where the ship carries the master station and establishes two slave stations on shore. Plotting is then done as a direct measurement of range from the two slave stations and a much greater area of high accuracy cover is obtainable. If desired, the master station can also be set up ashore and the system used as a conventional "Decca" chain. The first operational two-range set has already been fitted in one of the larger ships and is now being used for the first time in a survey off the West Coast of Scotland. Besides her equipment of two or three 28ft surveying motor boats, one or two 27ft surf boats, and a motor dinghy, every surveying ship also carries a Land Rover and trailer. Surveying motor boats all have plotting tables and echo-sounding gear and can also carry R/T sets, "Decca" sets and wire sounding machines. They are very seaworthy and can accommodate the crew overnight. Though a a certain percentage of the crews are specialists (known as Surveying Recorders, or S.R.'s), all members of the ship's company assist in the work of survey, whether it be as camp parties, boats' crews, erecting marks ashore, or operating radar, asdic or echo-sounding sets.

Modern Pyrite Plant Opened in South Australia

BY A CORRESPONDENT

SOMETHING like 100,000 acres have been added annually in recent years to the primary production area of South Australia, thanks to the use of superphosphate. Whilst import restrictions have become more severe, the demand for superphosphate throughout the continent has continued to expand, and as long ago as 1951 the urgent need for sufficiency in local supplies of sulphuric acid was regarded as urgent. For over eighty years it has been known that in the hills of South Australia, some 3 miles north of Nairne, there exists a vast deposit of iron pyrites (sulphide of iron), the lode being traced over a distance of miles.

Various investigations have been made by people searching for metals, but until 1951, when there was a world shortage of sulphur, little thought had been given to the extraction of this commodity. About that time also, supplies of zinc concentrates from Broken Hill, which until then had been used to provide some of South Australia's sulphur requirements, were transferred to Tasmania. Three enterprising South Australian fertiliser companies accordingly decided to join the Broken Hill Proprietary Company, Ltd., in forming the Nairne Pyrites, Ltd., to develop and work these Nairne deposits. The new company received substantial financial assistance and encouragement in many forms from the South Australian Government, and in the spring of this year, Mr. Playfair, the State Premier, opened their modern £1,500,000 plant at Brukunga, 3½ miles from Nairne, for quarrying the stone containing pyrites, crushing it and separating out the pyrites over 40 per cent of which is sulphur. He described it as a major asset and of the utmost importance to industry, and to the increasing development of the State's primary producing areas. The plant, in fact, assures the primary industries of adequate supplies of sulphur—an essential raw material in the manufacture of sulphuric acid for the production of superphosphate and also of great importance from the defence aspect. World supplies of sulphur are at present reasonably plentiful, but the South Australian demand for superphosphate has doubled since prewar, and now requires 150,000 tons of sulphuric acid for which 50,000 tons of sulphur are needed every year.

The Nairne plant will have an output of 30,000 tons of sulphur per annum, which will more than halve the imported supplies and, incidentally, save over £500,000 annually in dollar currency. Over a length of 1 mile, drilling has proved 50,000,000 tons of ore—sufficient for 150 years at the present rate of consumption.

The pyrite deposit at Brukunga (an aboriginal word meaning "fiery stone" and the name given to the new township) is about 300ft wide and extends more than 3 miles along a general north-south line, dipping steeply to the east. The rock containing the sulphides appears to have been a finely bedded mudstone. The sulphides present are pyrite and pyrrhotite in varying amounts, together with a little marcasite and traces of arsenopyrite, chalcopyrite, and sphalerite. The pyrite occurs in prominent bands following the bedding or foliation of the rock.

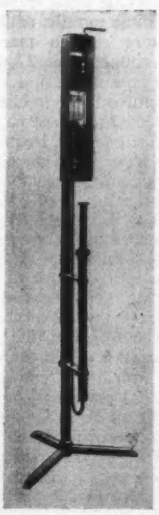
Brukunga ore is won by open cut quarrying, using a 120 Ruston Bucyrus 4 cubic yards shovel, and 20-ton Mack end-dump trucks for transport to the crushing plant. Here it is first passed through a 60in by 40in Ruwolt primary crusher, and then to the secondary crushers, which are 4ft "Traylor" gyratory machines with a 2in discharge setting. It then passes through a screening plant to the Symons 4ft standard tertiary cone crushers, and from these through the rod and ball mills to the flotation section. The flotation section consists of three banks of No. 21 "Denver" cells, each bank consisting of eight cells; two are rougher cells, and the remaining bank cleaner cells.

The concentrates are thickened, then passed to the agitators, and then to the filter house, which contains an 8½ft diameter disc filter, and provides sufficient space for the installation of a second filter of the same kind. The filter cake drops from the filter on to an 18in conveyor belt discharging into the hopper of the swivel piler. This unit projects the concentrates into the storage shed, and pivots about a vertical axis to give comparatively large storage with limited head room. From the shed, the concentrates are trucked to a siding at Nairne, and there transferred into railway trucks for transport to the works of Sulphuric Acid, Ltd., at Birkenhead.

As in the case of the iron ore deposits at Whyalla and Yampi Sound, the establishing of a new industry has created a new town. The township of Brukunga came into being with the construction of men's quarters and a messroom, which went into use in February, 1952. Since then, the settlement has grown rapidly and a housing scheme comprising fifty-seven bungalow type homes and three brick staff homes erected by the company forms the nucleus of the township.

Vacuum Gauge

THE McLeod gauges used in the testing of vacuum pumps and similar ranges of pressure have now been modified into a less delicate instrument, for production applications, by Pulsometer Engineering Company, Ltd., Nine Elms Iron Works, Reading, Berks.



McLeod gauge for vacua down to 0·00001mm

Whilst it was impossible to avoid completely the comparatively fragile gauge head, the design which has been newly developed employs a shrouded case for the glass part and robust metal tubes for the barometric leg and mercury container. The gauge head is joined to the metal tubes by means of conventional "O" ring sealed vacuum unions and can quickly be replaced in the event of breakage.

Gauge heads are produced to a standard calibration so that standard charts may be used, and replaceable heads can be employed with existing charts with a minimum margin of error. Standard ranges are from 0·1mm to 0·00001mm and 10mm to 0·01mm.

The complete gauge, which is finished by stove enamelling, weighs 35 lb.

RUBBER IN ENGINEERING.—A one-day conference on the use of rubber as an engineering material has been organised by the Natural Rubber Development Board and will be held on Thursday, September 27th next in the lecture hall of the Institution of Electrical Engineers, Savoy Place, London, W.C.2. The following six papers will be presented at the conference:—"Recent Advances in the Engineering Use of Rubber," by Dr. W. J. S. Naunton; "Load-Deflection Relations and Surface Strain Distributions for Flat Rubber Pads," by Dr. A. N. Gent; "The Use of Rubber in Engineering," by Mr. S. W. Marsh; "Dynamic Fatigue Life of Rubber Components," by Mr. P. W. Turner, and "Rubber in Agricultural Engineering," by Mr. S. J. Wright.

Industrial and Labour Notes

Trends in Capital Investment

The Treasury's recent *Bulletin for Industry* contains a review of the growth of investment in this country over the past four years, and of the variations which have taken place in the rate of investment in different categories. The general trend has been one of rapid increase, since 1952, an increase which is continuing in 1956, as far as can be seen from preliminary figures, in spite of the restraining measures which have been imposed. Taking the year 1950 as 100, the "gross fixed investment" remained roughly stationary until the last quarter of 1952, and then increased steadily to about 130 in mid-1955. But investment in housing rose to a peak of over one-and-a-half times its 1950 rate, in 1954, and then decreased again. However, in 1954 and 1955 manufacturing industry's share of total investment increased rapidly, but was still, late in 1955, slightly below its figure for 1950–52. The rise in fixed investment in the manufacturing industries in 1955 accounted for nearly two-thirds of the total increase in fixed investments, and was equal to about 27 per cent (by value) over 1954. The motor industry, the paper and printing industry, and the metal-using industries (other than vehicles) were particularly active in these expansion programmes. A point of interest is the comparison given between investment per head of the population in this country and in West Germany. In 1952 the German figure became equal to our own, and has since outstripped it. In 1950 the dollars invested per head were for this country and West Germany about 133 and 117 respectively, corresponding figures for 1955 being about 167 and 187.

According to recent returns to the quarterly inquiry of the Board of Trade into capital expenditure during the first three months of this year, the capital expenditure of the manufacturing industries in this country was 27 per cent more than in the corresponding period last year. Revised estimates returned by industry show that this year it is expected to invest some 18 per cent more in plant, machinery and equipment than last year and 33 per cent more in buildings. These revised estimates replace the provisional figures given to the Board of Trade at the beginning of July. The biggest increases are made by companies operating in the treatment of non-metalliferous mining products, which now anticipate a 7 per cent rise against an earlier forecast of a decline of 20 per cent, and the paper and printing trades which expect to spend an additional 52 per cent against the 31 per cent rise previously predicted. The motor vehicle industry's revised forecasts show that spending will go up by only 22 per cent instead of the previously estimated 30 per cent. Shipping companies, which originally forecast no change compared with their forecast expenditure for 1955, now expect a 12 per cent rise and the "other industries" group anticipates a 20 per cent increase instead of one of 12 per cent.

Restrictive Trade Practices Act

The president of the Board of Trade recently announced in a written reply in Parliament that the Board has made the first Registration of Restrictive Trading Agreements Order, requiring registration of restrictive trading agreements under the Restrictive Trade Practices Act, 1956. The president explained that if the order received the approval of Parliament it would come into force on November 30, 1956. During the three months following that date, particulars of the classes of agreement specified in the order must be furnished to the registrar of restrictive trading agreements. The specified classes of agreements are, broadly, those which include restrictions as to prices or other terms or conditions or which involve collective discrimination. These, it was pointed out, are the most important and the most numerous kinds of agreement. They include agreements about common prices and conditions of sale, agreements about level or agreed tendering, agreements under which preferential terms are granted to certain persons or traders and agreements under which supplies of goods are confined to certain persons or traders.

Agreements which contain restrictions affecting exports and which do not affect supply to the home market, do not have to be registered but must be notified to the Board of Trade. Under the provisions of the Act some restrictive trading agreements, as for example sole agency, patent and trade mark agreements are, in certain specified circumstances, exempted from registration.

United Kingdom's Export Trade

In the course of an address to the East and West Ridings Regional Board for Industry, in Leeds recently, the export trade of the United Kingdom was reviewed by Mr. A. R. W. Low, the Minister of State, Board of Trade. After discussing the wool textile industry, and the important part Yorkshire had played in the increase of engineering goods exports during the past two years, Mr. Low pointed out that it was estimated that this country's average monthly export of engineering equipment in the first half of 1956 was some 20 per cent higher than that in 1954. In value the increase was higher : engineering exports had earned £114 million more in the first half of this year than in 1955 and £141 million more than in 1954. The total exports of this country in the first half of 1956 were valued at £1591 million, compared with £1393 million in the same period last year. Making allowances for dislocations caused by the dock strike in October, 1954, there was an underlying rate of increase in our exports of about 10 per cent in value and 6 per cent in volume.

The Minister went on to say that recent world trading conditions had been very favourable and exports of manufactured goods in the world had been increasing rapidly. An increase of 14 per cent was shown in 1955 as compared with the previous year, and preliminary figures for the first six months of this year indicated that world trade was still rapidly expanding. This country had, however, not been able to take full advantage of the favourable conditions and its share of world trade in manufactured goods fell from 20·4 per cent in 1954 to 19·8 per cent in 1955. It was doubtful if we had increased our share of world trade this year so far, whereas Germany's exports had increased by 20 per cent.

Big changes had been made in this country's production and exports. Exports in radio communication and navigational air equipment were some six times higher than in 1948 and 46 per cent more than in 1953. Agricultural tractors earned nearly £25,000,000 in the first six months of this year, as compared with £19,000,000 in 1948; similar large increases were also to be seen in the exports of commercial vehicles and aircraft and parts. Despite the fact that this country was doing well in some exports, said the Minister, it could and must do much better. Our competitive position was improving, but of the main elements in world competitiveness, price was of growing importance. Mr. Low indicated that it was therefore essential that we should rid the country of inflation.

British Road Services

The British Road Services board of management has announced the plans for the organisation and operation of British Road Services as a result of the Transport (Disposal of Road Haulage Property) Act, 1956. As from September 9th next the business will be conducted through five operating companies. The British Road Services, Ltd., will operate 7750 vehicles on general haulage ; B.R.S. (Pickfords), Ltd., with 1350 vehicles, will operate special traffics and some of the transport contracts ; and there will be three other concerns—B.R.S. (Contracts), Ltd., B.R.S. (Parcels), Ltd., and B.R.S. (Meat Haulage), Ltd., operating with 1000, 4400 and 500 vehicles respectively. The shares of each of these companies will be owned by the British Transport Commission. The shares of the B.R.S. (Parcels), Ltd., and B.R.S. (Meat Haulage), Ltd., are subject to disposal, but the new Act makes it possible to defer their sale for the present.

A board of management, with Major-General G. N. Russell as chairman and managing director, will exercise control of the various operating companies through their boards of directors. The general pattern of executive management will remain unchanged with the country divided into six geographical divisions—with one division, B.R.S. (Pickfords), Ltd., for special traffics.

Fuel Statistics

The statistical statement of the Ministry of Fuel and Power for the week ended July 28th last, shows that coal production dropped to 3,484,500 tons as compared with 3,690,100 tons the previous week. This fall in output can be attributed to the annual holidays, 869,700 tons being lost through recognised holidays as compared with 886,900 tons the week before. Disputes resulted in a loss of 31,700 tons during the week under review. The production of opencast coal increased to 280,500 tons, and was well above the weekly average for the year. At 150,000 tons the coal exports for the week were the lowest for a month, and the imported tonnage of 70,900 tons was the fourth lowest this year.

In the week ended July 22nd the gas available at gas works totalled 9,287,600 million cubic feet as compared with 9,315,900 million cubic feet the previous week. The electricity sent out for public supply from solid-fuel-fired stations that week totalled 1,163·2 million units, bringing the total for the year up to 45,666·5 million units.

Pensions and National Insurance

The recently issued report of the Ministry of Pensions and National Insurance shows that at the end of 1955 the combined cost of the social benefits being paid was at the rate of £850 million a year. Under the National Insurance schemes, the amount paid in benefits during the financial year ended March 31, 1955 was £552 million.

During 1955 there were 831,000 claims for injury benefit and the cost in the year ended March 31, 1955 was more than £10,500,000. The rise in the number of claims for disablement benefit—a marked trend noted in last year's report—still continued.

The number of national insurance contributors at March 31, 1955, was nearly 23,750,000 or whom over 16,000,000 were men. About 21,750,000 were employed persons ; nearly 1,500,000 self-employed ; and over 500,000 non-employed. In the year ended March 31, 1955, the National Insurance Fund income was £612 million, over £489 million coming from employers and insured persons and £71,000,000 from the Exchequer, while £51,500,000 was income from investments of this fund and the National Insurance (Reserve) Fund.

Steel Investment in Western Europe

A correspondent of the *Financial Times* reports that the annual investment survey of the European Coal and Steel Pool anticipates that there will be bottlenecks at successive stages of steel production in Western Europe. Coal supplies will be insufficient for the planned coke oven capacity and coke supplies will be insufficient for the production of pig iron required for the projected steelmaking. No shortage of iron ore is expected. Some 151 million dollars will be invested this year in pig iron production, with new furnaces in Germany, Belgium and Luxembourg, and 103 million dollars will be invested in steelmaking plant. It is expected that by 1960 the six countries concerned will be capable of producing 98,000,000 tons of iron ore and about 55,000,000 tons of pig iron.

Multi-Spindle Automatic Lathe

BY OUR SOUTH AFRICAN CORRESPONDENT

THE six-spindle automatic lathe, here described and illustrated, was designed and constructed in South Africa by Mr. E. Faccio, the South African born proprietor of E.F.A. Engineering, Heriotdale, Johannesburg. As a machine of this kind was required for the production activities of the company, inquiries were made for the purpose of purchase. These inquiries, however, indicated that a machine of the capacity, rigidity and accuracy required did not appear to be obtainable from the stock or catalogue patterns available either in Europe or America, so the decision was made to proceed with its construction locally. When inquiries were first made regarding the possibility of obtaining a machine of the kind required, it was specified that it must have a turret stroke of 9in and a guaranteed tolerance of not more than ±0·0005in in the diameter of all work produced. It was also specified that the machine was to have six spindles operating simultaneously.

From the inquiries made it appeared that it was not possible to obtain a guarantee of a smaller tolerance than 0·001in between spindles and that no machine could be made available under the specification conditions laid down, having a stroke greater than about 6in. As the machine was required for medium batch production, the use of interchangeable cam gear for setting the machine to suit the many different types of workpieces to be produced was not favoured on account of the time required to change over from one type of workpiece to another. A further and very important point was that the machine was to be required to produce fairly large batches of workpieces involving the drilling of 2in diameter holes, and few of the designs offered were capable of withstanding for long the resultant thrust loads. For this machine a feed mechanism has been designed which eliminates entirely any need for cams or cam changing and permits of more robust construction.

A constant rate of rapid approach is provided for each of the six cross slides (Fig. 1), while at the same time the feed may be varied for each during simultaneous operation. Four of the cross slides can be seen in Fig. 1, and a particular point to be noted is that the tool points are always clear of the chuck centring jaws when attached to any position inside the area of the slides. This is a commendable feature, since it enables tools to be set with the minimum of overhang.

In construction the spindle carrier was jig-bored with a tolerance error of no more than 0·0002in between any of the spindle and indexing elements. The jig boring machine available had graduated scales some 3ft from the boring spindle, and these scales could not therefore be used for the purpose in hand. An ingenious geometrical method of setting and boring out the spindle centres was, however, devised, in which the apices of a set of equilateral triangles provided the centres of the spindle housings and indexing pinholes. The *modus operandi* in setting out these centres and in boring out for the housings and spindles may be followed by reference to Fig. 3.

The drilling for the main central spindle housing was first effected by jig boring the spindle carrier. On the main spindle C a central jig D with one spring-controlled centralising element was mounted, carrying an arm A, to which was affixed a 2½in diameter dial gauge. This gauge was set to zero when the distance between the centres of C and S_1 was 10½in. After boring out for S_1 a second arm B was similarly mounted on S_1, the arm A having been rotated to coincide with position S_2. The distance S_1S_2 is then fixed at 10½in, arm B having its dial gauge set to zero. This process, after boring in each case, is repeated through S_3, S_4, S_5 and S_6. Determination of the final distance S_1S_6 to be closed as 10½in ±0·0002in ensured that the error was no more than that laid down at the outset.

The machine has eight speeds ranging from 87 r.p.m. to 780 r.p.m., and twenty-four feeds ranging from 0·0026in to 0·128in per revolution, both speed and feed variations being provided by pick-off gears. Lubrication is by pump delivery under pressure from a sump located in a section of the machine base beneath the spindle frame, the oil being first delivered to the cam mechanism housed in the casting at the left-hand end (Fig. 2). The oil is delivered at the rate of 3 gallons per minute and passes on to a reservoir at the head of the spindle frame. From there it is drip-fed by gravity to all the moving parts beneath.

Cooling is effected by two coolant pumps, one at the front and the other at the rear, the cutting fluid being conveyed to all cross slide and turret stations. Located immediately under the lower cross slides are the sump and chip pans, the remainder of the machine base being ribbed in such a way as to ensure that the sump cannot be by-passed and that there is a uniform turnover of coolant with absence of stagnation flow areas.

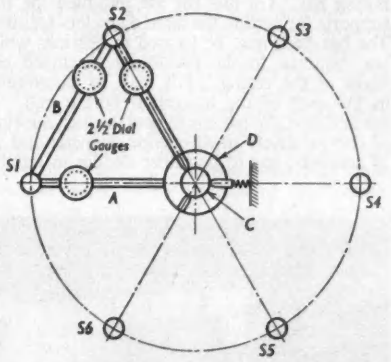
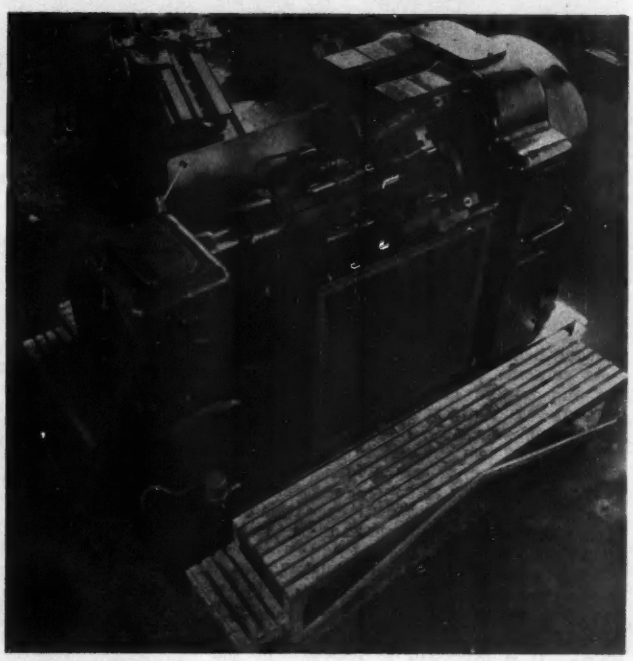


Fig. 3—Diagram illustrating how the spindle centres were set out to an accuracy of 0·0002in

The following data will give some indication of the size of the machine :—weight, 12 tons approximately ; overall dimensions, 11ft 6in long, 7ft 6in high, and 5ft wide. The compressed air chucks are 9½in diameter and the machine can handle workpieces 8in diameter and 8in long. It is chain driven by a 25 h.p. motor. All castings are of "Mechanite."

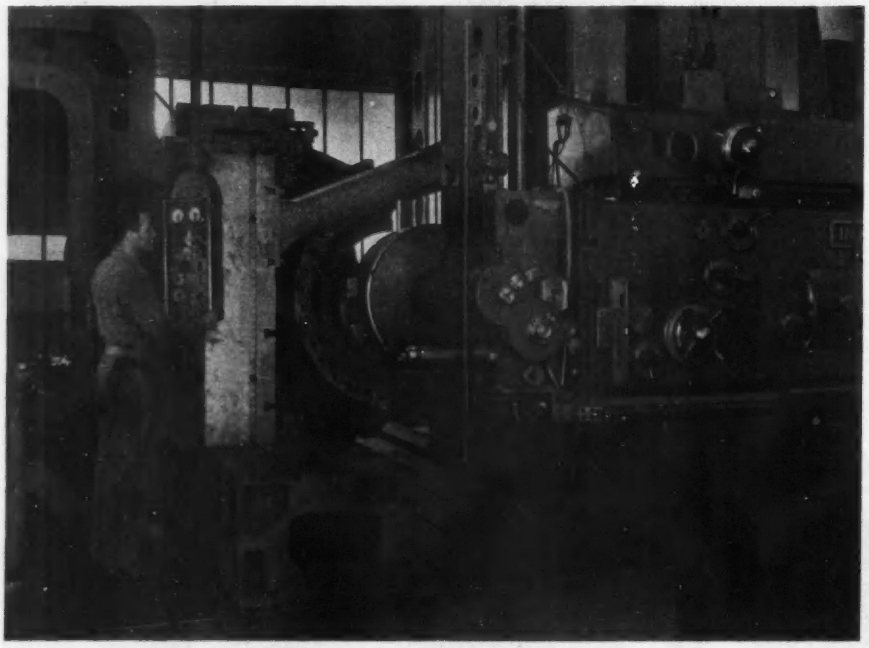
The machine has now been in use continuously on eight-hour-day shifts for three months on the production of high-precision products, and in that time has turned out much useful and valuable work. As an instance, 3000 pieces drilled to 2in internal diameter, as well as quite a few other simultaneous operations, involving a heavy total thrust on the machine, was completed in 150 hours. It is of interest to record that provision has been made for the attachment of an auxiliary gearbox to the top of the casting at the left-hand end (Fig. 2) of the machine. This gearbox will enable single-point chasing to be performed, the motion of the threading tool being similar to that of the "Cri-Dan" screwing machine. This gearbox is now ready for installation and use on a number of workpieces awaiting completion.



Figs. 1 and 2—Six-spindle automatic lathe built in South Africa for precision work. The lathe has eight speeds from 87 to 780 r.p.m. and feeds from 0·0026in to 0·128in per revolution. The turret stroke is 9in and 2in diameter holes can be drilled

Machining of Turbine Casings

In the machining of steam turbine casings, it is the practice to machine the insides of the two halves of the casing separately by means of a boring bar. On this bar are mounted the tool supports for cutting the large diameters required. The bar itself may be located in bearings which are mounted in the previously machined end bores of the casing, or it may be cantilevered in the quill of the horizontal boring mill. In the first case, the bar has to pass through bushings of comparatively small outside diameter and so, of necessity, has to be rather slender in relation to its long span and the heavy supports it has to carry. A quill-mounted bar also often lacks the desired degree of rigidity. All these factors tend to increase the difficulties of obtaining the accuracy required and matching the two halves exactly. The machining proceeds slowly, as only relatively light cuts can be taken.



The turbine casing is set up with its half-face in the vertical plane and finish machined on all external and internal surfaces without re-setting

As concerns the difficulty of matching the top and bottom halves of the casing, this problem was attacked by using a special boring bar adjustable from one end, which enabled the two halves to be machined assembled. However, it was found impossible to remove the swarf effectively, and difficult to take measurements and to observe the conditions of the tool without periodic dismantling. Hence, the method was abandoned.

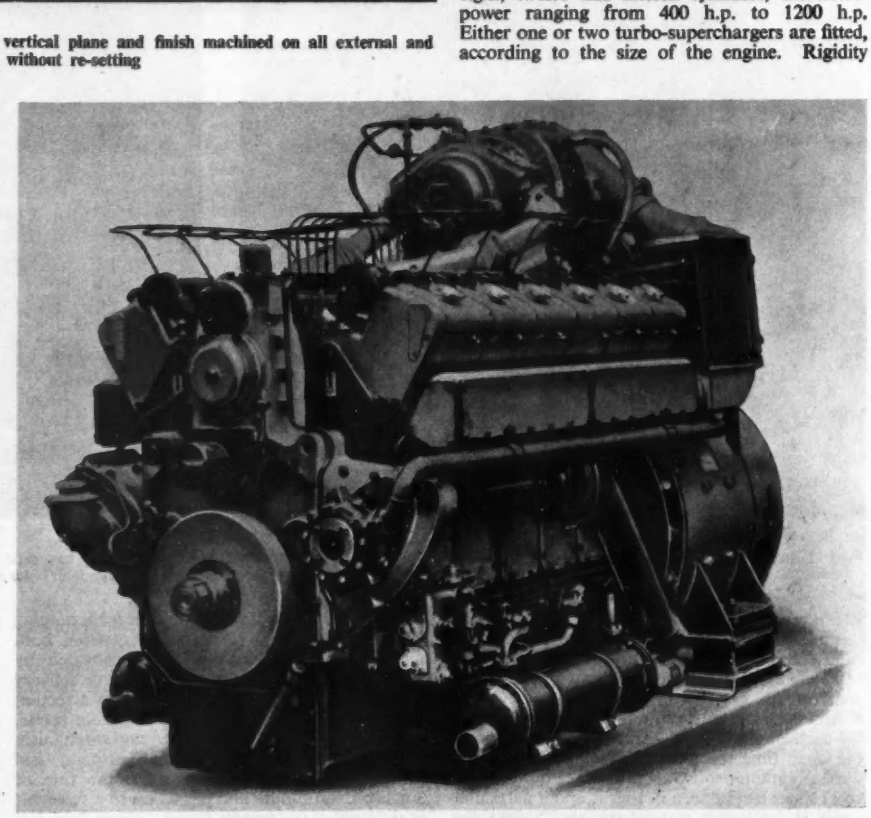
A solution to the problem of machining turbine casings expeditiously and with the required high degree of accuracy was indicated at a recent demonstration given by the firm of Innocenti, of Milan. It is proposed, as indicated in the accompanying illustration, to mount the work-pieces with their half-faces in the vertical plane, and, in addition, to set up the two halves either side by side or one above the other. In general, the halves would previously have been rough machined on the half-faces and ends.

In the machining demonstration, only one half-casing, made of cast iron, was used. It was set up as illustrated on the table of a "Model FAF 305/200" Innocenti-C.W.B. boring mill. With this design of boring mill, the headstock itself can be advanced in the direction of the boring spindle. About 75 per cent of the weight of the headstock is hydraulically counter-balanced, the balance being maintained for all headstock positions by compressing a system of disc springs by means of a wedge cam carried on the headstock. All movements are actuated by separate electric motors with Ward-Leonard control; the lead screws are stationary, while the nuts revolve, and all slides are floated on oil under a pressure of 400 lb to 600 lb per square inch. The thickness of the oil film under the column is stated to be of the order of 0·0015in. Its existence enables the 92-ton column, with its 19-ton headstock, to be moved by as little as 0·0003in, as, of course, all "stick-slip" friction is absent.

For the purpose of machining turbine casings, a special right-angle milling head has been designed, which can be bolted to the headstock as shown. The boring spindle, which is supported in preloaded, taper roller bearings, has its centre line offset about 1½in from the attachment base. On the spindle is mounted the boring head, consisting of a face plate of the required diameter on which is carried the radial tool slide. The face plate has on its circumference either an external or internal gear driven from the attachment by a pinion. Radial advance of the tool is obtained by a gear drive through the hollow boring spindle, through a train of gears the casing of which is visible on the near side of the attachment. A second drive pinion is also provided on the near side, so that the facing and boring head can be mounted either right or left hand, the radial feed gear being placed on the opposite side. The machine is completely controlled in all its movements, including tool feed, from the pendant shown in the illustration. In order to machine two casings to match exactly, it is proposed to machine each radial dimension (such as, for instance, a groove) in turn on each casing, using a dial gauge to maintain the radial tool setting, and the preset longitudinal or vertical stops of the machine for traversing from one workpiece to the other. A finishing cut over the half-faces and ends can also be taken without the necessity of altering the position of the workpieces. Normally, the operator stands between the workpiece and the machine column, where he obtains a good view of the tool and of the surfaces which are being machined. The U.K. agent is Henderson and Keay, Ltd., 189, Pitt Street, Glasgow, C.2.

Medium Horsepower Diesel Engine

Our illustration shows a diesel generator set powered by an "M.G.O." engine. Such engines are built under licence by Société Alsacienne de Constructions Méchaniques, Mulhouse (France), to the design of Société Civile d'Etudes Marep-Grosshans-Ollier. It is a four-stroke, direct injection engine, with cylinders arranged in a 60 deg. vee, and a bore to stroke ratio of approximately 1 : 1. Built for a speed of 1500 r.p.m., it is supplied in three versions, with eight, twelve and sixteen cylinders, the horse-power ranging from 400 h.p. to 1200 h.p. Either one or two turbo-superchargers are fitted, according to the size of the engine. Rigidity



Generator set for diesel-electric locomotive, powered by 900 h.p. diesel engine

coupled with high power-weight ratio have been the objectives of the design, which is also stated to achieve a fuel consumption of 0·330 lb per horsepower-hour or better.

Ease of maintenance has been another design objective. The crankshaft is underhung and held in thin wall, steel-backed copper-lead bearings. The connecting rod assemblies, comprising the pistons, master connecting rod and articulated connecting rod, can be replaced through the cylinder liners without the use of a lifting device. Power take-off is at either end of the crankshaft, with numerous take-off points for auxiliary equipment. A remote-controlled, all-speed governor is fitted. The engine is intended for use on locomotives and in other traction work, in drill rigs and pipeline pumping stations, for electricity generation, as a main propulsion unit for small vessels such as tugs, fishing and small cargo boats, and as a prime mover for auxiliary marine equipment.

Forthcoming German Engineers' Meetings

It is announced that the VDI/VDE Process Control Section is arranging a meeting, to take place in Heidelberg from September 25th to 29th, which will deal with the question of modern theories in process control and their application. The meeting will hear twelve general and over sixty special lectures, the latter dealing with a wide variety of topics from this field. The talks will be given by experts from a number of European and overseas countries, including the U.S.A. and U.S.S.R.

On October 4th and 5th the annual meeting will take place in Wiesbaden of the V.D.I. Section, "Heating, Ventilation and Air Conditioning."

The annual V.D.I. meeting of process engineers is to take place from October 1st to 3rd in Hamburg. The meeting will be addressed by Professor K. Riess (Leverkusen), who will speak on the subject of "Process Engineering in Germany and the Lack of Process Engineers in the Consumer Goods Industry"; Professor M. Bense (Stuttgart), who will speak on "Technical Integration"; and Professor R. Plank (Karlsruhe), whose talk will be on "Process Engineers in the Frontier Region of Chemistry and Technology."

A meeting on the problems of textile machine design will be held in M. Gladbach on October 12th and 13th.

Those wishing to obtain detailed information on any of the above, except the Hamburg meeting, should write to the Verein Deutscher Ingenieure, Düsseldorf, Prinz-Georg Strasse 77/79. For the meeting in Hamburg persons interested should write to the V.D.I.-Fachgruppe Verfahrenstechnik, Frankfurt/Main, Rheingau-Allee 25.

High-Voltage Transmission Lines in Sweden

According to the Swedish State Power Board, 380kV transmission lines which first came into operation four years ago will, by 1958, comprise a network totalling 1900 miles. An addition to these super-grid lines, which operate on alternating current, is the 100kV d.c. submarine line to the island of Gotland, which was put into operation in 1954. It is now considered technically feasible to raise the voltage of the 380kV lines to 450kV or even 500kV. The insulation of the present lines is said to leave a sufficient margin for this to be done, provided surge voltages are reduced. In order to avoid radio interference a third conductor would have to be added in each phase, and existing transformers would have to be rewound or supplemented with booster transformers. One solution would be to use 450kV at the transmitting end in the north, and to allow the voltage gradually to drop to 400kV in the south.

Studies are now in progress concerning a 650kV transmission system, such a voltage being considered the maximum which it is possible to use for such a purpose. With series capacitor compensation, a 650kV line using four bundled conductors is said to have a capacity of 2000MW. Together with the four 380kV lines running from north to south, which will be in service in 1960, two or three 650kV lines would be sufficient for all future power transmission in Sweden.

The alternative to these a.c. lines is the use of high-voltage direct current. Development work is proceeding in order to provide ionic valves of a larger capacity and for a higher voltage than the valves used in the 100kV Gotland transmission, and design studies are being made for ±400kV. Such a line would have about the same transmission capacity as a 650kV a.c. line, but it would seem to be too early to be able to compare the relative advantages and disadvantages of the two methods, or to decide whether the extra-high voltage lines would, in fact, be economically justified.

Convention of Chemical Science

The Convention of Chemical Sciences, 1956, will take place in Paris from November 18th to December 3rd, at the same time as the Fourth Salon de la Chimie-Caoutchouc-Matières-Plastiques. It will include several meetings of particular importance, notably the twenty-ninth International Congress of Industrial Chemistry, the first European Congress of Corrosion, the European Conference of Chemical Engineering and the Paris technical meetings.

The twenty-ninth International Congress of Industrial Chemistry will hold its sessions from November 18th to 24th at the Maison de la Chimie. It will consist of twenty-one sections which will deal with the main technical problems which are of interest to those industries in which production is based on chemistry. The first European Congress of Corrosion will also take place from November 18th to 24th at the Maison de la Chimie. Its work will be divided into eight sections which will be concerned with all aspects of corrosion and means of combating its effects. The European Conference of Chemical Engineering will include three symposia on the following subjects:—Calculations of converters, calculations of reactors, and extraction by solid adsorbents. These will take place in the conference hall of the fourth Salon de la Chimie, in the Palais des Congrès at the Porte de Versailles on November 22nd, 23rd and 24th.

The Paris technical meetings will be held at the same place and will include a series of specialised symposia dealing with such subjects as polar and tropical equipment, plastic materials, natural and synthetic rubber, control and regulation, analysis and methods of testing, and high grade and special steels. The fourth Chemical Rubber and Plastics Exhibition will open on November 22nd and will last until December 3, 1956. It will cover an area of nearly 4 hectares at the Parc des Expositions, Porte de Versailles. Over a thousand exhibitors of equipment, processes and products will be represented. Those interested should write to the Secretariat, Société de Chimie Industrielle, 28 rue Saint-Dominique, Paris (7e).

Annual Report of a Hamburg Oil Company

According to its recently published annual report, Esso A.G., Hamburg, retained its average share of the German market in petroleum products during the last financial year. Its total turnover of DM.1416 million constitutes an increase of 27·1 per cent compared with 1954. If taxes are deducted, net takings amount to DM.1047 million, an increase of 22·7 per cent, compared with expenditures amounting to DM.1059 million. With non-recurring profits and those from participation in other enterprises, to the total of nearly DM.21,500,000, a profit of DM.9,800,000 was obtained, to which must be added an amount carried forward of DM.11,300,000. At the annual general meeting on July 13th, a decision was taken to increase the existing capital by DM.61,300,000 to DM.200 million.

In the course of the last financial year the refinery at Hamburg-Harburg had a throughput of over 2,000,000 tons of crude petroleum, an increase of 25 per cent over 1954, and three times the figure for 1952. In spite of this increase, the import of refined products had also to be increased.

Projects to the value of DM.50,000,000 were completed and others to the value of DM.14,000,000 are still under construction. The first stage of the planned refinery at Cologne is to give an annual output of 3,000,000 tons from 1959 onwards, and the second stage, which is scheduled for completion in 1961, is to have an output of 5,000,000 tons per year, making a total for both refineries of 7,500,000 tons crude oil per year. First stage construction at Cologne, it is stated, will cost about DM.200 million, while the share in the proposed North Sea-Rhine pipeline is expected to require another DM.50,000,000 to DM.60,000,000. A hydrofining installation for desulphurisation came into operation last November, and a catalytic reforming plant (hydroforming) is to be started up shortly. The further utilisation of refinery gases is to be made possible by the construction of gas separation plant and tank storage plant. In December last year the company employed approximately 4300 people.

An announcement regarding Waried Tankschiff Reederei G.m.b.H., made at the annual general meeting, is dealt with in the following item.

German Tanker Line

It has been announced that on July 13, the German tanker line, Waried Tankschiff Reederei G.m.b.H., of Hamburg, a sister firm of Esso A.G., changed its name to Esso Tankschiff-Reederei G.m.b.H. All board members of the company are also on the board of Esso A.G.

Waried was founded in 1928 as shipping firm for the then Deutsch-Amerikanische Petroleum-Gesellschaft, which in 1951 was renamed Esso A.G. In those days the DAPG already had a long tradition in the tanker business, for its co-founder, Wilhelm Anton Riedemann, had begun the carrying of petroleum in the sailing ship "Sophie" in 1876. At the end of the 1930s, the Waried fleet comprised two high-seas tankers, one coastal tanker, and two coastal tank barges, in addition to which the company operated three DAPG tankers under charter, and had charge of twenty-seven high-seas tankers of the Panama Transport Corporation. After 1945, there remained only the coastal tanker "Senator."

To-day, Esso Tankschiff Reederei is the largest German undertaking in its field, and possesses six high-seas tankers totalling about 135,000 tons deadweight, of which four are turbine-driven vessels of 26,650 tons deadweight, and two are motor vessels of 15,250 and 13,625 tons respectively. In addition, there are a coastal tanker, a coastal tank barge, an inland waterways fleet of thirty-eight motor barges and barges, and two harbour tugs. A number of other vessels, including ten German ones, are under long-term charter. A further nine super-tankers, each of 36,000 tons deadweight, have been ordered by Esso A.G. from German yards, these ships to be delivered from 1958 onwards.

North Sea to Rhine Pipeline

The foundation of a company with limited liability for the construction and operation of an oil pipeline from the North Sea to the Rhine has been announced by the German firms Esso A.G. Gelsenberg Benzin A.G., Ruhrbau-Mineralöl Raffinerie G.m.b.H. Ruhrchemie A.G., Scholven-Chemie A.G., and Union Rheinische Braunkohlen Kraftstoff Aktiengesellschaft. No decision has been taken so far on whether Wilhelmshaven or Rotterdam is to be the seaport from which the proposed pipeline will start.

Sud-Est Aviation

It has been announced that the Société Nationale de Constructions Aéronautiques du Sud-Est (S.N.C.A.S.E.) is to be known, as from August 28th, as Sud-Est Aviation, Société Nationale de Constructions Aéronautiques. The company, makers of the jet airliner S.E. 210, "Caravelle," have their new address at 37, Boulevard de Montmorency, Paris (16e).

Forward Scatter of Wireless Waves

BY OUR AMERICAN EDITOR

Because of the current general interest in the "forward scatter" mode of wireless wave propagation and the importance of the subject to telecommunications, the National Bureau of Standards, Washington, D.C., has conducted intensive experimental and theoretical investigations in this field during the past few years. This work has been sponsored by the U.S. Department of Defence and has comprised studies of ionospheric forward scatter, tropospheric forward scatter and the theory of forward scatter in general.

IT is believed that the forward scatter mode of wireless wave propagation will extend greatly the limits of long-distance communications. Through the application of scatter propagation new frequency channels can be opened up to long-range use, new path lengths can be utilised, and reliable service can be provided far beyond the line-of-sight limit in the extreme high-frequency ranges. Both industry and the American armed services anticipate savings to be obtained by this method through the elimination of many relay stations.

Wireless propagation by forward scatter is believed to result from small inhomogeneities due to turbulence in the atmosphere. These inhomogeneities scatter wireless waves in all directions, but predominantly forward. With properly designed equipment, the scattered signal can be received over long distances along the earth's surface even though the direct wave has gone off into outer space. While this phenomenon has been known for several years, extensive research has been necessary before it could be successfully applied to wireless communications. For more than five years, forward scatter has been the subject of intensive experimental and theoretical investigation at the National Bureau of Standards. Sponsored by the U.S. Department of Defence, this work has not only provided insight into the nature and causes of the scattering process but has also laid much of the groundwork for an effective application of forward scatter in practical communication circuits.

The N.B.S. programme has included both ionospheric and tropospheric forward scatter. Ionospheric scattering takes place in the lower part of the ionosphere—a region of electrified particles 40 to 200 miles above the surface of the earth. Tropospheric scattering occurs in the part of the atmosphere that lies below the ionosphere. Tropospheric forward scatter appears to be useful for transmissions over distances up to 600 miles, such as in air-to-ground communication between an aircraft in flight and its control tower, at frequencies from 100 to at least 10,000 Mc/s. Ionospheric forward scatter permits communication in the frequency range from 25 to approximately 60 Mc/s and over distances extending from approximately 600 to 1200 miles.

Beginning with frequencies where wireless waves are no longer reflected by the ionosphere, as they are in ordinary long-distance transmissions, ionospheric forward scatter extends into the very-high-frequency (v.h.f.) region, a part of the wireless frequency spectrum which was formerly considered useless for long-distance communication on a regular basis. In the regions where transmission is by tropospheric scatter, the available frequencies are increased many fold. Scatter propagation also helps to fill in gaps of path lengths that have not been satisfactorily covered. The N.B.S. research in both these areas has progressed simultaneously. The tropospheric programme has been centred at Boulder, Colorado, with the principal transmitters on Cheyenne Mountain, near Colorado Springs, and receiving stations in eastern Colorado and Kansas. The ionospheric work has utilised a variety of paths to evaluate variables such as the effects of the auroral zone. One of these paths—between Cedar Rapids, Iowa, and Sterling, Virginia—has been used continuously for nearly five years.

Ionospheric Forward Scatter

When wireless waves were first discovered, they were shown by physicists to be transverse electromagnetic waves identical to those of light except for their frequency of vibration. It was, therefore, believed that they would no more go beyond the visible horizon than would light rays bend around a corner. Thus, when Marconi showed in 1901, that wireless waves could be received across the Atlantic Ocean, there was at first no satisfactory explanation for his observations. The search for such an explanation eventually led Heaviside and Kennelly to propose that high up in the atmosphere there are layers of electrified particles, or ions, capable of reflecting wireless waves much as a mirror reflects light waves. Thus, wireless waves can be propagated far beyond the visible horizon by reflection from these ionised layers, which are known collectively as the ionosphere. Ionospheric reflection has been for years the basis of all wireless communication links more than a few hundred miles in length.

The scattering of wireless energy by the ionosphere is similar to the scattering of light by small water droplets in a cloud or fog. When a beam of light shines through the mist, moving points of light are seen in the beam. These are water droplets, ordinarily too small to be seen, scattering light out of the beam towards the observer. Similarly, the irregular variations in the structure of the ionosphere are believed to result in the scattering of wireless waves. Ionospheric forward scatter is characterised by its high reliability under practically all conditions. During auroral disturbances, which cause polar blackouts of ordinary high-frequency ionospheric communication, scattered signals usually become stronger. Also, strengthening is often observed during sudden ionospheric disturbances, which are associated with solar flares and cause short-term blackouts of high-frequency communication throughout the daylight hemisphere. Such auroral storms and polar blackouts constitute one of the more serious problems in arctic communications. Hitherto attempts have been made to obtain reliability during such disturbances by changing the frequency of operation. This, of course, requires the installation of multiple transmitters, aerials and receivers. A single ionospheric scatter circuit, while expensive in itself, can provide more reliable service at a single frequency and less total cost.

It is generally agreed that scattering takes place from that part of the lower ionosphere known as the *E* region. Ionospheric layers exist in this region at various heights, usually between 80km and 110km above the earth's surface. Ordinarily, wireless waves of frequencies up to about 25 Mc/s pass directly through the *E* layers and are reflected from outer layers, usually in the *F* region. However, there is some property of the *E* region which causes v.h.f. wireless waves to be scattered in all directions when they strike it. This scattering can occur due to a large number of small irregularities in the ionisation of the atmosphere, much as light is scattered from the large number of small water droplets in a cloud or fog. A very small portion of the scattered energy will reach a receiver which is pointed directly toward the spot where the incident wave strikes. This principle may be utilised for wireless communication if: (1) the wireless wave is transmitted with sufficient power; (2) the transmitting aerial has high gain and is properly directional, and (3) a high-gain directional receiving aerial is used. It is believed that at least three major factors contribute to the ionisation of the *E* region, which causes ionospheric scatter: direct solar radiation, corpuscular radiation and meteors. The contributions of each mechanism are not known exactly and more study of the whole subject is needed. In a series of measurements over an arctic path (Anchorage to Barrow, Alaska) correlation with magnetic activity indicated a rise in signal strength at the receiver with increasing magnetic activity at the midpoint of the path (Fairbanks). One explanation for this phenomenon is that the contribution of the corpuscular radiation factor at these times is high. Corpuscular radiation, which is presumably of solar origin, consists of atomic particles of matter. These particles take from eighteen to thirty hours to reach the earth from the sun. When they enter the earth's magnetic field, they are caught up by it and spiral toward the pole. The net result is more ionisation in the lower region of the ionosphere.

According to one school of thought ionisation by meteors is the dominant mechanism. Literally millions of tiny particles of meteor dust enter the earth's atmosphere every day, but usually burn themselves out before striking the surface. Their passage through the atmosphere produces trails of intensely ionised gas which scatter wireless waves. The meteor theory maintains that there are enough meteors to produce a continuous mechanism for the propagation by the overlapping trails of ionisation, and that this is the dominant contribution to the received signal. There is experimental evidence that this is true at some times of the day, particularly in the early morning hours.

The principal factors which limit the utilisation of ionospheric forward scatter are frequency and distance. The experimental approach has been to isolate the different variables and evaluate them individually. However, it has been difficult to express a relationship with frequency. The useful frequencies employed are between 25 and 60 Mc/s. The signal strength falls off very rapidly as the frequency is increased. Thus the lower frequencies of the range will generally permit the more efficient transmission. However, if too low a frequency is chosen, ionospheric reflection will also take place at certain times, and then the scatter circuit may be affected by multi-path propagation of its own transmission or by other transmissions, or it may cause interference in other circuits.

Distance dependence is governed largely by (1) the magnitude of the scattering angle, and (2) the height of the layer of the ionosphere that produces the scatter. The scattering angle is defined as the angle between the incident wave and the scattered wave that reaches the receiver. As observed in the N.B.S. tests, the strength of the scattered signal falls off very rapidly as the scattering angle is increased. This occurs as the path is shortened, and at less than about 600 miles the ionospheric signal becomes too weak for practical use. At the longer distances, the signal intensity is usable because the angle is small, until the limiting distance is reached. The maximum distance is reached when the portion of the ionosphere from which scattering occurs meets the horizon as "seen" from the transmitter. An increase in aerial height helps slightly toward increasing the distance range.

In 1913, Kennelly suggested the possibility that wireless waves might be scattered as well as reflected by the ionosphere. In 1932, Eckersley proposed a theory of scattering to account for certain special effects he observed, but no one appears to have seriously proposed ionospheric scattering as a useful communication mechanism until 1950. In December of that year a group of scientists holding a conference at the Massachusetts Institute of Technology suggested that scattering in the ionosphere might produce a signal sufficiently strong to be useful, provided a strong transmitter, high-gain aerials and a sensitive receiver were used. A co-operative experiment was promptly arranged in which the M.I.T. Lincoln Laboratory sponsored the operation of a transmitting site by the Collins Radio Company, at Cedar Rapids, Iowa, while the National Bureau of Standards operated a receiving site at its field station at Sterling, Virginia, the distance involved being 773 miles. After experimental transmissions during the next month had demonstrated that signals were continuously received and that they exhibited interesting and promising behaviour during ionospheric disturbances, a programme of further experimentation was formulated. Transmissions on 49·8 Mc/s over the original path have continued

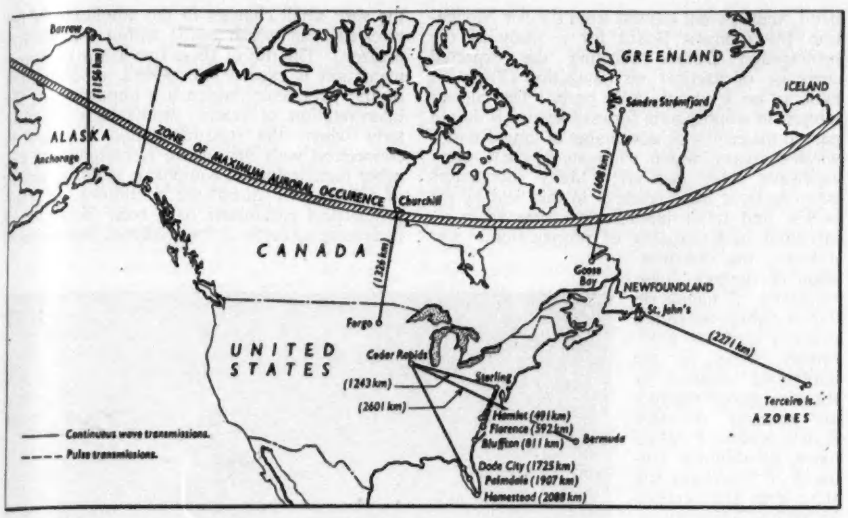


Fig. 1—Experimental paths being used by the National Bureau of Standards in its ionospheric forward scatter research work

without interruption since January 23, 1951. The programme has subsequently been enlarged in various ways, but always with the dual objective of (1) investigating the physical principles and theories involved in ionospheric scatter, and (2) providing engineering information for the design, construction, and operation of communication systems. The work at the N.B.S. has been carried out under the sponsorship of the U.S. Department of Defence and the U.S. Air Force.

In addition to the Cedar Rapids - Sterling path, which has been operated continuously, several other paths (Fig 1) have been studied for shorter periods. Since the method offers the advantage of reliability during ionospheric disturbances, such as auroral storms and polar black-outs, three paths were established in regions where the aurora is most active. One, from Fargo, North Dakota, to Churchill, Canada, terminated practically in the zone of maximum auroral occurrence. The other, from Anchorage to Barrow, Alaska, crossed the maximum auroral zone practically at the mid-point of the path. An ionospheric station at Fairbanks provided soundings at the approximate mid-point. These paths were almost the same length as the Cedar Rapids - Sterling path, so that effects due to differing distances were eliminated. Another auroral-zone path was also tested in 1952 and 1953 from Goose Bay, Labrador, to Sondre Stromfjord, Greenland. Much valuable data on the characteristics of these paths were obtained. The investigators found that with careful design of the path components, it was possible to communicate with very high reliability even in these regions where communication by ionospheric reflection is often badly disrupted by natural phenomena. A path from St. John's, Newfoundland, to Terceira Island, in the Azores, gave an opportunity to study problems associated with extreme distance—1411 miles in this case. Here the terrain was such that high aerial sites could be chosen overlooking the ocean. Under these circumstances it was verified that a distance of 1400 miles was feasible for reliable operation. An interesting aspect of this test is that it combined frequency-standard techniques and propagation measurements in improving the efficiency of the test set-up. Portable standard-frequency oscillators developed by the Bureau were employed at both the transmitter and receiver to permit using a 40 c/s receiver bandwidth at 36 Mc/s transmitter frequency. This reduced the necessary transmitter power and aerial gain by improving the signal-to-noise ratio of the circuit.

In addition, short-term experiments for studying other variables utilised other paths, mostly originating from Cedar Rapids and from Sterling. Tests of reception near the maximum distance were carried out from Cedar Rapids to Dade City, Palmdale and Homestead, all in Southern Florida. In 1952 and 1954 short-distance tests were made from Sterling, Virginia to Bluffton, South Carolina. In these tests the time of arrival of ionospheric scatter waves was compared with that for more direct tropospheric signals. This gave direct evidence concerning the height of the scattering layers. In 1951 an attempt was made to look for scattering from higher layers, such as the *F*2, on a path from Cedar Rapids to Bermuda. This path was chosen as being sufficiently long so that the lower layers would be well beyond the horizon. At the frequency used—near 50 Mc/s—occasional weak signals were observed, and these were attributable to other mechanisms. As part of the United States participation in the International Geophysical Year, it is planned that the N.B.S. will carry out in 1957–58 an ionospheric scatter experiment in Peru, where the midpoint of the path will be nearly at the geomagnetic equator. This experiment will determine scattering behaviour in a geographical region having ionospheric characteristics not previously studied from the scattering standpoint. The possibility of high-level scattering in that region will be investigated.

Large rhombic aerials have been used at both ends of the path for most of the experiments. Where space and suitable terrain were not available for rhombic aerials, "Yagi" arrays (Fig. 2) were usually substituted. To obtain a suitable comparison between the different aerial designs various combinations were installed at several transmitting and receiving sites. In some experiments transmitter and receiver were switched alternately between two aerials at half-hour intervals. For example, a combination of rhombic to rhombic and Yagi, and of Yagi to rhombic and Yagi, was operated for a time between Anchorage and Barrow. Here the two receiving aerials were used simultaneously and continuously. For continuity in observations on the Cedar Rapids-Sterling path the rhombic aerials were always used as the reference pair. Rhombic aerials up to twenty-five wavelengths on a side have been constructed. For a frequency of 50 Mc/s, which is approximately that used on all paths except Newfoundland-Azores, this means a distance of 500ft on a side. The construction and successful application of aerials of such size confirmed the belief that conventional designs of rhombic aerials could be extended to larger sizes. In order to study aerial patterns and to help in predicting performance, scaled systems were constructed. If the system is scaled small enough, experimental measurements can be made within a reasonable distance of the aerial. Precise scale models of the aerials were thus studied systematically at the Bureau's model aerial ranges at Sterling, Virginia and Boulder, Colorado.

In view of the promising characteristics of the new mode of ionospheric propagation in Arctic regions, the U.S. Air Force asked the Bureau in 1951 to assume the responsibility for setting up the first regular communication circuit using ionospheric scattering in the v.h.f. range. Initially a 48 Mc/s experimental one-way circuit was tested between Labrador and Greenland. This was followed by a completed prototype system operated at frequencies between 30 and 40 Mc/s, consisting of three two-way circuits extending from Maine to Northern Greenland. Recently this system has been extended under N.B.S. supervision from Goose Bay, Labrador, via Narsarssuak, Greenland, to Reykjavik, Iceland. The detailed engineering design was worked out with the help of the E. C. Page Consulting Radio Engineers and the installation contract was awarded to that firm. Since only a small portion of the transmitted signal is scattered by the ionosphere, it was necessary to use large amounts of gain in such a communication system. This called for powerful transmitters, high-gain aerials and sensitive receivers. The operating circuits that have been installed use 40kW transmitters, high-gain aerials designed by the N.B.S., and sensitive receivers designed by the Lincoln Laboratories of M.I.T. The complete four-channel multiplex wireless teletype systems began operation in 1953. After a brief trial period the prototype circuits were made available to the Air Force for test traffic. A careful attempt was made to obtain accurate performance reports and to provide information on the problems and weaknesses of these facilities. In the first year, traffic utilisation was achieved 91 per cent of the time, and propagation difficulties accounted for circuit outage only 1·1 per cent of the time.

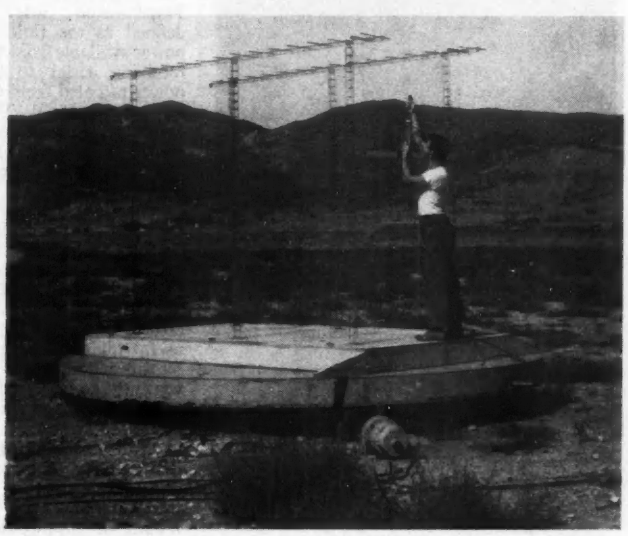


Fig. 2—Scale model of "Yagi" aerial array being tested at N.B.S. model aerial range

Tropospheric Forward Scatter

Until fairly recently, distances much beyond the horizon of a wireless transmitting aerial were considered too great for useful communication links at frequencies above 100 Mc/s, and distances of less than 1000 miles were considered too short for good ionospheric propagation. It is just

this range of distance which is important in the application of forward scatter techniques. For propagation paths between 600 and 1200 miles only the ionosphere will support measurable scatter signals. However, for distances shorter than about 600 miles and at frequencies above 100 Mc/s, observed scatter signals are tropospheric. The usefulness of the ionospheric scatter mechanisms ceases at about 60 Mc/s, while tropospheric propagation promises to be useful for communication purposes from 60 Mc/s up to frequencies exceeding 10,000 Mc/s.

Like ionospheric scattering, tropospheric scattering is caused by small inhomogeneities in the atmosphere. However, in tropospheric scattering the incident wireless energy does not affect the electrical properties of the medium, except in the centimetre wave region, where absorption effects are important. Thus, in contrast to ionospheric scattering, tropospheric scattering is not very frequency-sensitive. At frequencies above 50 Mc/s, climate, weather and terrain irregularities play principal parts in determining the strength of a tropospheric signal and the distance through which it will be propagated. Above 1000 Mc/s (or below a wavelength of 30cm) the effects of atmospheric absorption become apparent; and at wavelengths of a fraction of a centimetre atmospheric absorption is by far the most important factor in the transmission loss or attenuation between transmitting and receiving aerial terminals. Radar meteorology makes good use of these absorption phenomena.

The last war accelerated the development of techniques and applications for the portion of the wireless-frequency spectrum above 50 Mc/s, which include radar, aircraft communications, navigational and guidance systems for aircraft, ground-to-ground wireless relay systems, a new system for broadcasting using frequency modulation, television, and many other services. At the close of the war the Central Radio Propagation Laboratory was established at the National

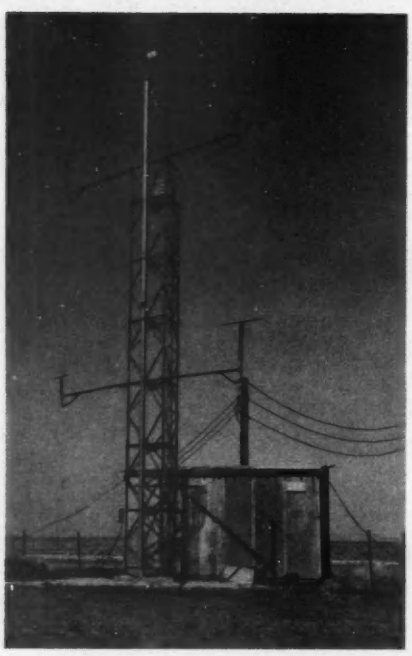


Fig. 3—Unattended receiver installation at Kendrick, Colorado, used in tropospheric scatter research work

Bureau of Standards to centralise and co-ordinate wireless propagation research. Since then, and particularly during recent years, several U.S. Government agencies have requested the aid of this laboratory with problems of frequency allocation in the v.h.f. and u.h.f. bands. Examples are the request by the Radio Technical Commission for Aeronautics for guidance in the allocation of air-to-ground communication facilities, the requirements of the Federal Communications Commission for additional information regarding propagation in the u.h.f. television band, and a recent request from the Air Navigation Development Board for a study of the propagation factors affecting the expected coverage of tactical air navigation (TACAN) facilities on a country-wide basis. The current interest in tropospheric forward scatter is due in part to the economic advantages of long-distance wireless relays, which eliminate a great many expensive relay stations. Many advantages accruing from basic research in this field by the N.B.S. and other laboratories come from an increased understanding of propagation. For instance, the determination of random phase variations of signals on line-of-sight propagation paths at v.h.f. and u.h.f. reveals some of the limitations imposed by the propagation medium on accurate direction finding systems. Furthermore, quantitative estimates of long-term and short-term time variability, such as fading ranges, fading rates, and signal continuity, are essential to the proper design and allocation of u.h.f. navigation facilities.

The systematic study of tropospheric forward scatter includes not only conventional techniques but also advanced concepts designed to explain and define observed scatter phenomena. The Bureau's activities in the field include investigations of such quantities as transmission loss, fading rate, fading range, phase variations, angular distance, obstacle gain due to diffraction and path aerial gain. This work has been sponsored by the U.S. Army Signal Corps and the U.S. Air Force. Transmission loss is defined as the ratio of power available from the receiving aerial to the power radiated from the transmitting aerial. This quantity has been used since 1952 to record the results of experimental and theoretical investigations at the N.B.S. because one of the characteristics of scatter propagation is that the system will not realise the gain of the aerials. Therefore, the usual specification of field strength in terms of effective radiated power is likely to be misleading.

Fading rate, or the number of times per minute that the envelope of a received field crosses its median level with a positive slope, is a useful quantity in studying propagation either by diffraction or by scatter. Fading may conveniently be classified into long-term and short-term variations of transmission loss. Long-term variations are caused by slowly varying changes in the propagation medium such as changes in the intensity of turbulence in the troposphere. Short-term changes are attributed to phase interference among simultaneously occurring modes of propagation, i.e. to multiple path effects. Recent work has indicated that fading rates within this line of sight are independent of frequency but depend upon the number of atmospheric inhomogeneities or "blobs" that cross the propagation path each minute.

Instrumentation has been developed to measure variations in the phase difference of waves travelling in a single path and of waves travelling in multiple paths. For a single path, variations are measured at the two ends of the path, while for a multiple path the variations in the phase difference between the waves arriving over the first path and those arriving over an adjacent path are measured simultaneously. In addition, instrumentation has been designed to measure the very small changes in the amplitude of the received field which occur within the wireless horizon. The use of these two kinds of instrumentation is expected to permit an evaluation of the parameters which are important in the interpretation of scatter mechanisms, particularly where the instrumentation is used in connection with microwave refractometers and other meteorological equipment under a variety of atmospheric turbulence conditions. Certain geometrical parameters have been found useful in developing methods for predicting transmission loss under a variety of conditions. One of the more important of these is the angular distance, θ, defined as the angle in the great circle plane between the horizon rays from the transmitting and receiving aerials as determined for a standard radio atmosphere—i.e. using an effective radius of the earth 4/3 times its actual value. Over a smooth spherical earth the angular distance is equal to the distance between the radio horizons of the transmitting and receiving aerials divided by the effective radius of the earth. The difficult problem of defining aerial height over irregular terrain becomes less important when angular distance is used as a parameter.

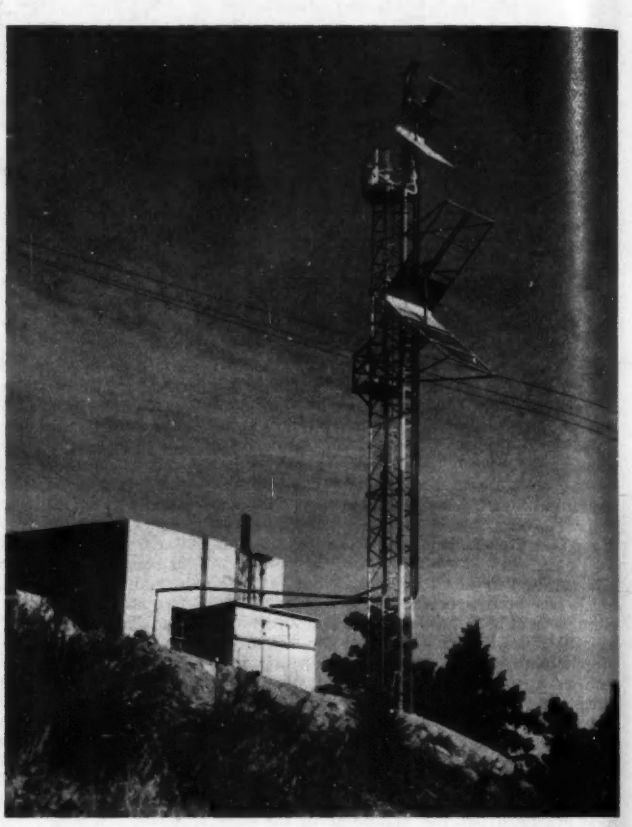


Fig. 4—High-power continuous-wave transmitter for the study of tropospheric forward scatter. It is situated at a low elevation on Cheyenne Mountain

Fading range is the difference in decibels between the instantaneous transmission loss levels exceeded 90 per cent and 10 per cent of the time during a short period such as one hour. It is convenient to consider received v.h.f. and u.h.f. fields as consisting essentially of two components. One has a slowly varying amplitude and results from some mechanism such as ground wave propagation within the horizon or diffraction accompanied by ducting or reflection from elevated layers in propagation beyond the horizon. Another component has a rapidly fluctuating amplitude and results from atmospheric scattering. In developing scattering and diffraction theories it is important to be able to separate these two mechanisms within the observations.

The use of angular distance in estimating transmission loss and fading range for propagation through a turbulent atmosphere over irregular terrain has provided a set of prediction

formulæ which agree very closely with observed six-month median values.—The observations include some 136,000 hourly median values of transmission loss, over 122 propagation paths at frequencies ranging from 66 to 1046 Mc/s. Large obstacles which act like single knife-edges in ground-to-ground propagation paths can effectively reduce transmission loss and fading below the amount observed with the forward scatter mechanism. Measurements have been made on several paths approximately 100 miles long, one of which passed over the Pike's Peak Mountain at an elevation of 14,109ft above sea level. When transmission was directly over the summit of the Peak, the signals were much stronger than when the path passed on either side. Very little fading was observed at this site. Transmission loss over a knife-edge is systematically less than that for propagation over a sphere, indicating the desirability of developing a method of calculation applicable more generally to obstacles of intermediate shapes. Such a method has been developed, depending upon the fact that transmission loss over a smooth sphere with distance and angular distance constant decreases rapidly as the effective radius of the sphere becomes less.

Research on tropospheric forward scatter at the Bureau has been continuous since January, 1949, when a large-scale programme of field strength measurement (Fig. 3) of frequency modulation and television broadcasting stations was initiated. Within two years the programme had grown with the assistance of the Federal Communications Commission, several universities, and other organisations, until at the end

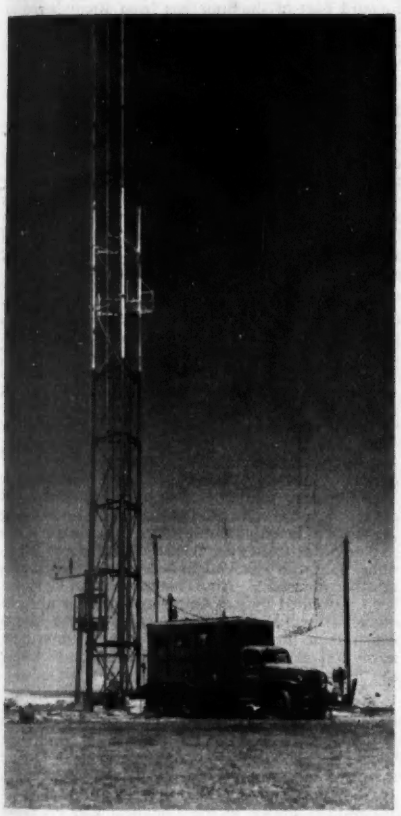


Fig. 5—Base of 500ft tower at the Haswell receiving station in Colorado, equipped with meteorological instruments to determine refractive indices

of 1951 long-term measurements were being obtained by sub-contractors over a hundred propagation paths scattered throughout the country. Data were supplied in the form of hourly median values of field strength and were recorded over some paths for several years. At the present time, more than half a million punched cards are available containing these data. By November, 1951, preliminary measurements had been made at a frequency of 1000 Mc/s out to a distance of several hundred miles from the N.B.S. Cheyenne Mountain Field Station in Colorado. This station had been established in June, 1950, to determine tropospheric propagation characteristics within, near and far beyond the radio horizon. At about the same time the Bureau's Tropospheric Propagation Research Section moved to Boulder, Colorado.

The facilities of the Cheyenne Mountain experiment include high-power continuous-wave transmitters on five frequencies, from 92 to 1046 Mc/s. Continuous recordings have been maintained for long periods at four fixed receiving stations situated up to 226 miles from the transmitters, and for shorter periods at semi-fixed installations at Anthony, Kansas and Fayetteville, Arkansas. These two installations are 393 and 617 miles, respectively, from Cheyenne Mountain (Fig. 4). The location of one of the transmitting aerials more than 3000ft above local terrain provides a simulated "air-to-ground" communication link. The area is ideal for meteorological studies because of the heterogeneous meteorology available. Facilities for determining the meteorology associated with tropospheric propagation in the Cheyenne Mountain experiment include a 500ft tower at Haswell (Fig. 5), Colorado, just beyond radio line of sight from Cheyenne Mountain, and portable equipment for determining pressure, temperature and humidity with conventional recording devices along the propagation paths. A resonant cavity microwave refractometer developed at the Bureau is used on the Haswell tower and in aircraft flights through the area to determine the refractive index of the atmosphere as a function of time and position in space. The refractive index is regarded as the most important of the meteorological parameters expected to correlate wireless and weather phenomena.

Several mobile recording units are available (Fig. 6) for measurements in the plains, foothills, and mountainous regions of Colorado. With this equipment, including a 100ft telescopic mast, it has been possible to investigate more thoroughly the effect of irregular terrain on v.h.f. and u.h.f. wave propagation. In general, higher propagation loss and greater ranges of variability are associated with the foothills terrain than with the plains, and correlations between observations of transmission loss tend to be mostly dependent upon the degree of separation of the propagation paths and much less dependent upon differences in frequency.

Meteorological and wireless data have been correlated over many paths in addition to those in Colorado and Kansas. A meteorological microfilm library, containing all North American surface and constant-pressure charts for the period from 1946 to 1951, provides a ready check for wireless data due to unusual meteorological conditions and forms the basis for correlation work with observed wireless transmission loss data. Based upon analyses which prove that there is a significant correlation between surface refractivity and wireless transmission loss along a path, 4,500,000 punched cards were obtained from the U.S. Weather Bureau to supply needed information about surface refractivity over the entire country. The measurement of wireless transmission loss and meteorological conditions concurrently over the same path and over a wide range of frequencies makes it possible to estimate missing values from the information obtained at 100, 200 and 1000 Mc/s.

Propagation by Scattering Due to Turbulence

The Bureau's experimental research on tropospheric and ionospheric scatter mechanisms has been accompanied by a study of the causes and theory of scattering due to turbulence.

The turbulence, more or less intense, which exists permanently in the atmosphere produces slight fluctuations of density. This causes the refractive index to vary by very small amounts at each point of the atmosphere, and these variations produce scattering. In the troposphere, the refractive index is a function of temperature and of water vapour content. In the ionosphere it is a function of the electron density. If the density of the air varies by small amounts, these quantities will vary and, in turn, will cause fluctuations of the refractive index. The Bureau's recent studies have shown that the density fluctuations are due to the vertical transport of masses of air (blobs) by the turbulent motions. Their amplitude depends on the difference between the normal or mean temperature gradient of the atmosphere and the adiabatic gradient, i.e. the theoretical gradient when there is negligible heat exchange. This effect is more important in the ionosphere than in the troposphere. In the ionosphere it is accompanied by fluctuations due to the vertical transport of the electrons, which have a distribution of their own different from the air density distribution. Also required is an accurate mathematical description of the fluctuations which can meet the test both of theory and experimental observations. There are two different mathematical descriptions of a field of these random fluctuations, one known as the auto-correlation function, the other called the statistical spectrum. These two descriptions are in principle mathematically equivalent, but the problem was to derive the correct expression. In previous works the correlation function was principally used, but it was chosen for mathematical convenience without full regard for the dynamics of the turbulence. However, taking the above considerations into account leads more naturally to the spectrum. The result finally obtained was found in remarkable agreement with the observations. It was also found that the "scale" of the turbulence could be obtained from the shearing effect of the differences of winds.

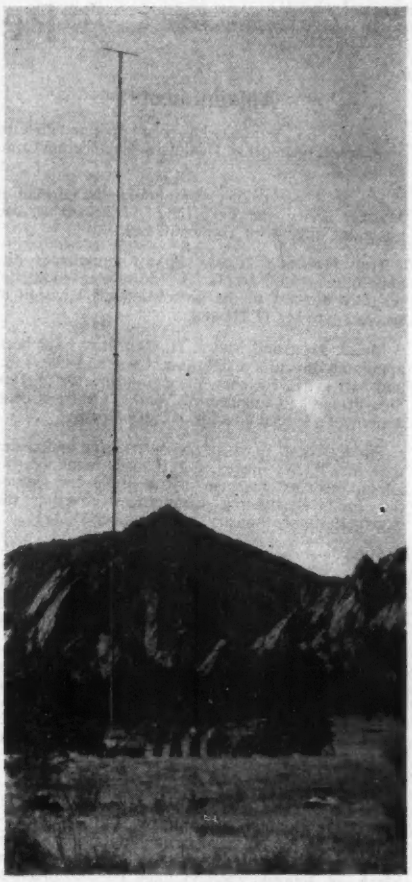


Fig. 6—N.B.S. mobile recording unit with 100ft telescope mast used to study the effects of irregular terrain on v.h.f. and u.h.f. wave propagation

From the spectrum of the refractive index fluctuations and from the electromagnetic equations, it was possible to obtain the scattering coefficient, i.e. the formula giving the power scattered as a function of the frequency and of the angle of scattering. Naturally, a correct expression must furnish the same results with the correlation function corresponding to the spectrum, through a different set of equations. By applying the spectrum derived from the study of the turbulence in this general expression, a coefficient was obtained which could be compared with the very precise observations at hand. Close agreement was found.

Personal and Business

Appointments

MR. G. N. F. WINGATE has been appointed director and general manager of Distington Engineering Company, Ltd.

MR. P. R. SCUTT has been appointed chairman of Masson Seeley and Co., Ltd. Mr. Scutt is also managing director of Tecalemit, Ltd.

THE NATIONAL COAL BOARD announces the appointment of Mr. E. S. Mosley as industrial relations director of the East Midlands Division in succession to Mr. H. Hicken.

MR. J. JACK and MR. J. H. PATCHETT have been appointed directors of Dorman, Long and Co., Ltd., and Mr. W. S. Fletcher, managing director of Tees Side Bridge and Engineering Works, Ltd., has been appointed a special director of the company.

THE CENTRAL ELECTRICITY AUTHORITY announces that Mr. E. W. Bussey, C.B.E., will relinquish his appointment as chairman of the employers' side of the Joint Negotiating Committees covering the electricity supply industry, on December 31, 1956.

MR. J. H. H. GILLESPIE, B.Sc., A.M.I.C.E., A.M.I.Struct.E., has been appointed engineer (maintenance and general), South East Division, British Transport Waterways. Mr. Gillespie was previously senior engineering assistant to the Clyde Navigation Trust.

THE BRITISH ALUMINIUM COMPANY, Ltd., announces that Mr. P. Ralph has been appointed vice-president of Aluminum Transatlantic, Inc., and Mr. R. A. Martin has been appointed manager of the company's Scottish branch sales office, 113, West Regent Street, Glasgow, C.2, in place of Mr. P. Ralph.

MR. E. T. GILL, B.Sc., F.I.M., has been appointed to the staff of the development and research department of the Mond Nickel Company, Ltd., as development officer for constructional alloy steels. He is taking up the position which became vacant when Mr. L. W. Johnson was appointed assistant manager of the department.

MR. W. F. ADAMS, B.Sc. (Eng.), A.M.I.C.E., A.M.Inst.T., has been appointed an assistant chief engineer in the highways engineering organisation of the Ministry of Transport and Civil Aviation. Colonel S. Green, O.B.E., T.D., A.M.I.C.E., has been appointed to be deputy to the Divisional Road Engineer, Metropolitan Division.

CROMPTON PARKINSON, Ltd., has appointed Mr. W. A. McNeill, B.Sc. (Tech.), M.I.E.E., M.Amer.I.E.E., to the post of deputy chief engineer and deputy manager, development and research department. In both these positions Mr. McNeill will be deputy to Mr. H. Astbury, M.I.E.E. Mr. McNeill was chief engineer of Cooke and Ferguson, Ltd., Manchester, and he will continue to act as technical adviser to that company.

COMPOFLEX COMPANY, Ltd., announces that, following the recent expansion and reorganisation of the company, the following appointments have been made. Mr. S. Polkinghorn, the general sales manager to be general commercial manager, with direct responsibility for both home and export sales; Mr. J. Pickthall, formerly Northern sales manager, to be home sales manager, assisted by Mr. C. V. Hadley, handling side, and Mr. H. J. Bergin. A newly formed export department is under the direction of Mr. A. R. Davies, and Mr. R. A. Usher has been appointed service manager.

MONSANTO CHEMICALS, Ltd., announces that, to meet the organisational requirements of the company's development programme, the following appointments have been made:—Mr. W. M. Thompson, director of purchases, to be sales director; Mr. J. S. Brough, chief engineer, to be general manager of production; Mr. J. S. Hunter, sales controller, to be general manager of development; Mr. W. E. Hamer, manager of research department, to be general research manager; Mr. J. M. Kershaw, project manager, to be chief engineer; Mr. D. C. M. Salt, sales controller, to be general manager of sales; Mr. G. Dodd, director and general manager of Monsanto Plastics, Ltd., to be controller of purchases, Monsanto Chemicals, Ltd.; Mr. E. L. Pixton, sales controller of Monsanto Chemicals, Ltd., and a director of Monsanto Plastics, Ltd., will, until further notice, be seconded to devote the whole of his time to promoting the present and future marketing interests of Monsanto Plastics, Ltd., and Mr. O. W. Murray, chief construction engineer, to be deputy chief engineer.

Business Announcements

STANDARD TELEPHONES AND CABLES, Ltd., has established a regional office, under the management of Mr. A. W. Hedley, at Coronation House, 69/71, Market Street, Manchester, 1.

THE LINCOLN ELECTRIC COMPANY, of Cleveland, Ohio, U.S.A., announces that it has terminated its association with Lincoln Electric Company, Ltd., of Welwyn Garden City, England. The sole distributor in the United Kingdom for all the firm's products is now Armco, Ltd., of 75, Grosvenor Street, London, W.1.

J. SAMUEL WHITE AND CO., Ltd., has purchased the whole of the share capital of Henry Bannister and Co., Ltd., rope manufacturers, of Cowes, Isle of Wight. The present directors have resigned and the new directors are as follows:—Mr. J. A. Milne, C.B.E., The Lord Glyn of Farnborough, M.C., D.L., Sir Charles Lillicrap, K.C.B., and Mr. R. Allen, A.M.I.Mech.E.

JOHNSON AND PHILLIPS, Ltd., announces that the transfer of the firm's switchgear department from Kidbrooke to New Cross was completed on Tuesday, August 7th. All correspondence with the switchgear department should continue to be addressed to the company at Victoria Works, Charlton, London, S.E.7. The switchgear department telephone number is now Tideway 5251.

PETTERS, Ltd., Staines, has purchased all rights in "Coborn" petrol engines from K. and L. Steelfounders and Engineers, Ltd. The manufacture of these engines has now ceased, although spares and service will continue to be available in all parts of the world. Spares will be supplied in future by Petter McLaren Service, Ltd., Burton-on-the-Wolds, Loughborough, and in most territories will be available from the previous Coborn agents.

CHARLES COLSTON, Ltd., announces that, under a reorganisation of its executive staff and its subsidiary companies, Mr. Michael Colston has been appointed acting director of research and development. A new bay at the Aycliffe factory of Tallent (Aycliffe), Ltd., has now been taken over by the firm, with Mr. A. R. Northover, a director of Tallent (Aycliffe), Ltd., as general manager. Mr. C. T. Howard retains his present responsibilities as director and general manager of Tallent (Aycliffe), Ltd. Mr. H. C. Addis, a director of Smith-Richards, Ltd., has, in addition, been appointed general manager of that company and Mr. A. Lukins has been appointed acting secretary.

THE PLESSEY COMPANY, Ltd., announces that in order to consolidate associations and agreements made with a number of United States companies in recent years, it has formed an American corporation for the representation and control of its interests in that country. The new corporation, to be known as Plessey Incorporated, has been constituted under the laws of the State of Delaware and has offices at 41, East Forty-Second Street, New York City. The Plessey offices in Chicago are being closed and, in future, all the company's American affairs will be handled centrally through the New York headquarters. The president of Plessey Incorporated is Mr. W. J. Sinsheimer.

Contracts

THE BRIGHTSIDE FOUNDRY AND ENGINEERING COMPANY, Ltd., has received a contract from British Insulated Callender's Cables, Ltd., for a semi-continuous copper rod mill for that firm's Prescot Works. The mill will have an output of some 50,000 lb per hour of high-quality copper rod.

DAVY AND UNITED ENGINEERING COMPANY, Ltd., is building a new four-high plate finishing mill for the Appleby-Frodingham Steel Company at a cost of over half a million pounds. This mill is being designed to roll plate up to 12ft wide, up to 4½in thick, and with a maximum length of 65ft. Fed by an existing roughing mill, it will initially be capable of producing about 9000 tons of plate in a week of three-shift working.

THE DE HAVILLAND AIRCRAFT COMPANY, Ltd., has received an order for fourteen "Comet" jet airliners from the Capital Airlines Inc. of the United States. The value of this order, including spare parts, is some £19,000,000, and deliveries will commence late in 1958. Four "Comet 4" aircraft will first be supplied, followed, in the latter part of 1959, by ten "Comet 4A" machines particularly intended for medium and short-stage operation. The "4A" aircraft will have a cruising speed of 545 m.p.h. and will accommodate seventy-four passengers. The aircraft will be fitted with Rolls-Royce "RA29" "Avon" jet engines.

THE ENGLISH ELECTRIC COMPANY, Ltd., has received a contract for the two largest steam generating sets yet ordered for installation in Australia from the Electricity Commission of New South Wales. The value of the contract is over £1,500,000. The turbo-generator sets, each of 100,000kW, are to be erected in Tallawarra power station, near Port Kembla, one of the largest steel centres in Australia. Each turbine will be coupled to a hydrogen-cooled alternator to generate power at 13·8KV. The award of this contract to English Electric Company, Ltd., follows an order placed with it last February by the Electricity Commission of New South Wales to build seven 330,000V transformers, the first of this size ever to be built in Britain.

Miscellanea

IMPORTS OF PAPERMAKING MATERIALS.—The Board of Trade has announced that from July 22nd imports of paper and paper board and of wood pulp and the other main papermaking materials are admissible from any source under the open general licence or under open individual licences. These arrangements do not cover newsprint or those kinds of paper and board hitherto admitted under the paper manufactures quota.

"VISCOUNT MAJOR" FLIES.—On July 27th the first Vickers "Viscount" 800 made its first flight from Brooklands to Wisby, Surrey. The 800 series aircraft have a 3ft 10in longer fuselage than the 700s, and take off at 62,000 lb instead of 60,000 lb. The rear pressure bulkhead has been moved aft to give total increase of 9ft 3in in cabin length, and the forward part of the floor has been strengthened to allow freight to be carried. Proposed cabin layouts vary from seventy-seat tourist to fifty-four-seat luxury versions.

POST-GRADUATE COURSES IN HIGHWAY AND FOUNDATION ENGINEERING.—The University of Birmingham is introducing post-graduate courses, lasting one year, in highway and foundation engineering. The courses will begin next October and will be in two main divisions, (*a*) the foundations of engineering structures, and (*b*) design of highways. Soil mechanics will be a common subject in both divisions. Division (*a*) continues with specialised applications of soil mechanics, and division (*b*) with traffic engineering and the construction and finance of roads.

ATOMIC ENERGY INVENTIONS.—The United Kingdom Atomic Energy Authority is taking steps to bring to the notice of industry many of the developments and inventions which have arisen out of the work of its research and industrial groups. The Authority now has a substantial holding of patents and patent applications which may be useful not only in the development of nuclear power, but also for more general purposes in the chemical, engineering, metallurgical and electronic instrument fields. A staff of patent officers attached to the Atomic Energy Establishment and the Industrial Group works closely with the scientists and engineers in assessing the value of inventions and taking appropriate action to patent them. In filing details they also give indications of the uses which might be made of the inventions in other industries. Mr. Thomas Benson Gyles has been appointed by the Authority to act as a liaison officer with industry, and to advise on the uses to which these inventions might be applied and the terms (on a non-exclusive basis) under which they can be used.

PETROLEUM EQUIPMENT MANUFACTURES.—The Council of British Manufacturers of Petroleum Equipment has issued its "Chairman's Report on the Work of the Council, 1955–56," which states that the British contribution to the industry's equipment in 1955 amounted to more than £123½ million. General attention is drawn to the Chemical and Petroleum Engineering Exhibition, to be held from June 18 to 28, 1958, at Olympia, London, and comment made upon the "Study Days" at Liége, held on May 2nd, 3rd and 4th. The report announces that the annual dinner is to be held on September 27th at the Dorchester Hotel, London, and that a "Spanish Edition" of *British Petroleum Equipment News* is planned for the autumn. There is a reference to expansion in refineries and during the ten years 1950–60 it is estimated that in the United Kingdom capital expenditure will amount to £1000 million, of which £340 million will be on refining and marketing. The value orders for oil equipment amounted to about £123½ million in 1955, compared with nearly £80,500,000 in 1954, while the report states that orders were received in the first quarter of 1956 to the value of nearly £38,500,000

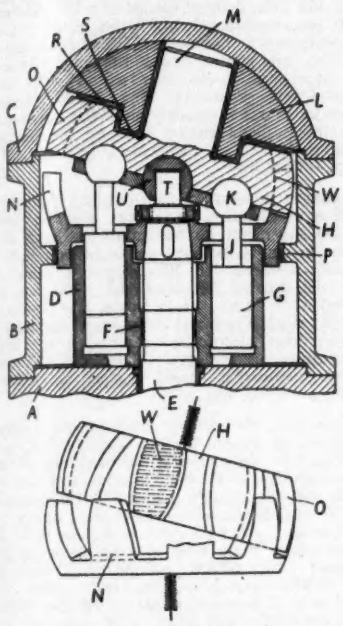
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

POWER TRANSMISSION

753,245. January 11, 1954.—SWASH PLATES, Walter Reiners, trading as W. Schlafhorst and Co., (22a) M. Gladbach, Rheinland, Germany.

The invention relates to swash plates for pumps or motors in which the swash plate has its axis inclined to that of the driving ring, and is driven by it through inter-engaging gear teeth. Its object is to provide an improved construction of the swash plate. As will be seen from the drawing, the housing



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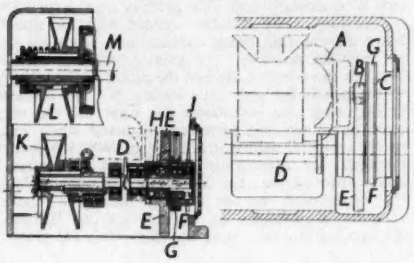
for a multi-cylinder swash plate pump is formed by a baseplate *A*, an intermediate member *B* and a cover *C*. A cylinder drum *D* is fitted on to a driving shaft *E* and connected to it by means of splines *F*, and receives pistons *G* connected to the swash plate *H* through piston-rods *J* and balls *K*. A rocking bearing member *L* for a shaft *M* which carries the swash plate is adjustably guided in the cover *C*. The swash plate is driven from the shaft *E* through rings *N* and *O* of gear teeth. The toothed driving ring *N* is keyed to the end of the driving shaft *E* and is supported in the annular flange *P* of the housing, while the toothed member *O* is supported radially on the annular flange *R* of the rocking bearing member *L* and axially against its front face *S*. The driving shaft is also connected to the swash plate through a ball joint, the forward end of the driving shaft *T* being a sliding fit in a bore formed in the central ball *U* carried by the swash plate. In accordance with the invention, the teeth *O* on the swash plate *H* are connected to the body, not in the usual way by their root faces, but through their end faces *W*. The lower view shows in chain line hatching the areas by which the teeth are secured to the swash plate. The position shown in the lower view is the maximum inclination of the swash plate. As the angular inclination is reduced more and more teeth come into engagement until when the axes are in line the teeth are all engaged, forming a claw coupling.—*July* 18, 1956.

751,616. January 22, 1954.—INFINITELY VARIABLE SPEED TRANSMISSION, Nederlandse Grossmann Maatschappij N.V., 10, Jupiterkade, The Hague, Holland. (*Inventor: Julius Hermann Grossmann.*)

The invention relates to an infinitely variable speed transmission for machine tools, such as grinding and buffing machines and lathes and other purposes. Its object is to provide an infinitely variable speed adjustment of from, say, 80 to 3000 r.p.m., which so far could not be accomplished. As will be seen from the drawing, the driving motor *A* has arranged on its shaft a gear wheel *B* and a belt pulley preferably of the "V" type *C*. A driven shaft *D* is furnished with a gear wheel *E* and a further belt pulley *F*. The gear wheels *B* and *E* are in mesh and the belt *G* connects the pulleys *C* and *F*. Between the gear *E* and the shaft *D* a freewheel device *H* to give one-way rotation is fitted. Also between the pulley *F* and the shaft *D* a second freewheel device *J* is fitted, giving a direction of rotation contrary to the device *H*. From the shaft power is transmitted through infinitely variable speed transmission comprising pulleys *K* and *L* to the driven shaft *M*. When the motor rotates in one direction



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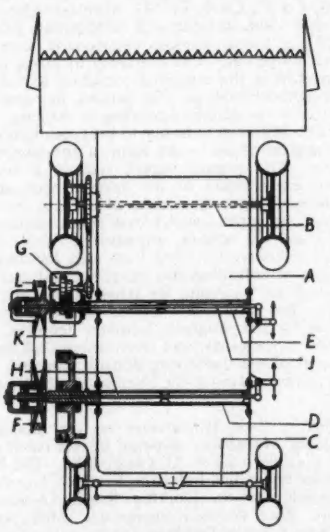
the shaft *D* is driven by the gear *B*, the gear *E* and the freewheel clutch *H*. When it rotates in the opposite direction the shaft *D* is driven by the pulley *C*, the belt *G*, the belt pulley *F* and the freewheel clutch *J*. The reversal of the direction of rotation of the motor, together with the different working effect of the gear transmission and belt drive, is utilised to provide a wide range of speed adjustment in accordance with the invention. The motor can easily be reversed by simple electrical means.—*July* 4, 1956.

AGRICULTURAL ENGINEERING

752,102. January 18, 1954.—CONSTRUCTION OF BODIES FOR COMBINE HARVESTERS, August Claas and Franz Claas, partners of Firma Gebruder Claas, of Harsewinkel, Westfalia, Germany.

The invention relates to a body or shell for use in a combine harvester, an object being to provide a body or shell for use in a combine harvester which has transversely arranged reinforcing or stiffening tubes of improved construction. Referring to the drawing, *A* is the combine harvester body with two axles *B* and *C*, which carry the wheels. Two reinforcing tubes *E* and *D* extend transversely across the body, being secured to each side wall of the body and protruding from the body at one side. A combine harvester driving part is mounted on the protruding end of the reinforcing tube *D*, a gearbox being mounted on the protruding end of the reinforcing tube *E*. A drive pulley is illustrated at *F* while the gearbox is shown at *G*. With variable speed transmission it is important to adjust or control the effective diameter of the variable pulleys, where possible, from within. The



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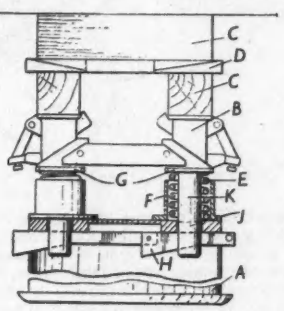
rods necessary for this purpose are located within the reinforcing tubes as illustrated in the drawing, in which *H* shows the rod operating the drive pulley, while *J* is the rod which passes through the gearbox. As illustrated, the arrangement may also be constructed in such a way that a revolving axle *K* of the gearbox is located in alignment with the reinforcing or stiffening tube *E*, and the axle is hollow so that the control rod *J* operating the adjustable disc *L* of a variable speed pulley passes axially through the revolving axle. It will be seen that the drive pulley *F* and the adjustable disc *L* are each mounted from the protruding portion of their respective reinforcing tube on a revolving axle located in the respective reinforcing tube. The invention provides a very simple form of attachment for the main drive pulleys, as well as for the gearbox, while at the same time the body of such combine harvesters is extremely sturdy. —*July* 4, 1956.

MINING ENGINEERING

753,216. May 27, 1952.—MINE ROOF SUPPORTS, The Mining Engineering Company, Ltd., Meco Works, Worcester. (*Inventor: Angus Wellesley Duncan.*)

The object of the invention is to provide a roof-supporting structure by which initial roof subsidence can be prevented or greatly reduced. As shown in the drawing, the chock structure comprises a fabricated base unit *A* substantially square in plan, chock releases *B* of known type, timber chock pieces *C* and pairs of wedges *D* which can be driven over



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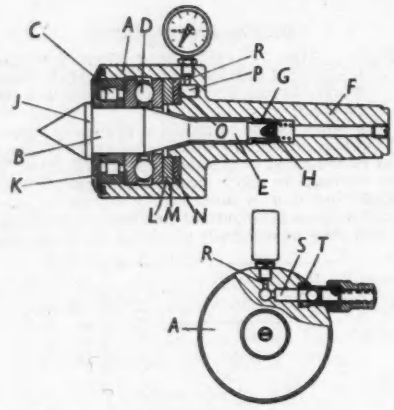
each other to tighten the chock between floor and roof. The fabricated base unit incorporates four compression springs *E* in housings *F* located at each corner and each bearing at one end against a plate *G* and at the other end against the base. Means for locking the springs in their fully compressed state comprise tension bars *K* depending from the plates *G* and wedges *H* which may be passed through slots *J* in the bars *K* to hold the plates against the housings. The wedges limit the vertical movement of the tension bars *K* and the plates *G* by expansion of the spring *E* under no load. In the extended position with no load on the chock, the springs are precompressed during assembly to about three-quarters of their total load. When the springs are fully compressed, the plate against which they bear rests on the tubular housing *F* for the spring. Before the chock is set for the first time it is necessary to compress the springs and lock them. The chock is then built up and tightened against the roof by means of the timber wedges *D* in the normal way. The spring locking means *H* are then released and the springs *E* expand, increasing the pressure of the chock against the roof. As the roof subsides the load on the chock increases beyond the spring loading and the springs are compressed until the plate *G* strikes the top of the housing *F* when the resistance of the chock becomes the crushing load of the timber members.—*July* 18, 1956.

MACHINE TOOLS

752,792. January 1, 1954.—LATHE CENTRES, Gunter Horst Rohm, Mühlstrasse 9, Sontheim (Brenz), Germany.

Referring to the drawing, the live centre includes a housing *A* within which a centre tip *B* is rotatably supported by an annular radial thrust bearing *C* and an annular axial thrust bearing *D*. The tip, has a shaft *E* which projects into the housing and into the tapered shank *F*. The shaft *E* is radially supported at its rear end by a needle bearing *G*. The socket formed in the shank *F* contains a compression spring which has a cap, which, in turn, supports a hardened steel ball *H* which acts as an axial bearing upon the rear end of the shaft and tends to return it to its normal position after axial displacement. A collar *J* on the centre tip bears against a protective cover *K* which, together with the bearings *C* and *D*, permits certain axial movement of the centre tip relative to the housing. An annular central portion on the rear wall of the cover *K* bears against the inner race of the roller bearing *C*, which thus transmits pressure exerted on the centre through the ball bearing *D* to a ring *L* which is slidable within an annular groove at *M*, forming a chamber. A ring *N* of elastic material having an annular groove *O*, which lies near the shank of the housing, is fitted in the groove behind the ring *L* and the space between the grooves is filled with a fluid. The elastic ring *N* tends to restore the tip to its normal position after axial displacement. The inner race of the bearing moves with the centre tip, but the outer race of the bearing is fixed relative to the housing. The annular groove *M* is connected

to a bore *P* from which two passages *R* and *S* extend through the outer wall of the housing *A*. The bore *P* as well as the passages are filled with oil or grease. The passage *R* is connected to a pressure gauge, while the passage *S* is connected to a pressure regulator *T* consisting of a ball which is slidably



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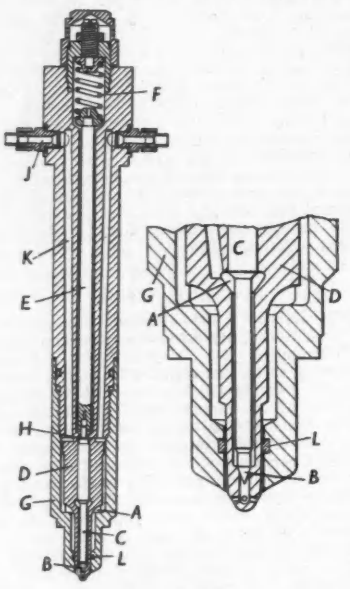
adjustable in a pressure chamber by means of a knurled screw. The ball is forced outwards by the fluid pressure and inwards by the screw. If the workpiece expands and a large pressure builds up in the groove *M* it may be relieved by unscrewing the screw and so increasing the effective volume of the chamber. Modifications are also shown in the specification.—*July* 18, 1956.

INTERNAL COMBUSTION ENGINES

752,913. March 5, 1954.—FUEL INJECTORS, Bryce Berger, Ltd., Ironbarks Works, Staines, Middlesex. (*Inventor: Geoffrey Ralph Green.*)

The invention relates to fuel injectors, particularly, though not exclusively, for internal combustion engines and more specifically to injectors which include cooling means. From the drawing it will be seen that the injector embodies the usual form of fuel circuit in which fuel enters by way of a feed pipe and through drilled and machined passages to an annular area *A* where it is sealed by a seating *B*



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of a needle valve *C* which is a close fit in a nozzle body *D* and held upon its seating by a spindle *E* under the adjustable influence of a spring *F*. Sealing of this circuit is effected by the pressure of a screwed sleeve or jacket member *G* exerted through the nozzle body *D* upon the lapped joint faces *H*. Fuel leaking past the lapped fit of the needle valve in the body is conducted via a passageway to a leak-off union and the high-pressure feed may be vented by the screw plug. The drawing shows the circuit provided for the coolant, which may flow in either direction. If the coolant enters by a union *J* it passes through a conduit *K* through cut-away portions of the nozzle body *D* to an annulus between the sleeve *G* and nozzle body which annulus connects the flow and return circuit. In accordance with the invention, a hydraulic packing or seal of resilient and heat-resistant material *L* is provided between the outside of the nozzle body part *D* and the surrounding sleeve or jacket *G* in the accompanying illustration. The packing comprises a resilient ring *L* which is of circular cross section when in free state, and this is so disposed that it does not apply any axial load to the nozzle body with the resultant risk of distortion and also permits axial expansion or contraction by slidable contact with the nozzle body *D*, the ring being carried in a recess in the surrounding sleeve *G*. No axial pressure is exerted between the nozzle body and the jacket in the vicinity of the nozzle tip and valve seating *B*. The resilient sealing ring also eliminates the need for the very close manufacturing tolerances involved when solid metal to metal sealing is attempted. While primarily intended for application to injectors for internal combustion engines, the invention also contemplates the application of the sealing means to cooled versions of injectors or burners for gas turbines, oil burning furnaces and the like.—*July* 18, 1956.

Technical Reports

Iron-Loss Tests on Transformers with Cores of Hot-Rolled and Cold-Rolled Silicon Steel (Ref. Q/T140). The British Electrical and Allied Industries Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey. Price 7s. 6d., postage 3d.—It has often been assumed that anisotropic (cold-rolled) transformer steel can be successfully used only if special kinds of core are employed, but there has been no published information as to the results which could be obtained using orthodox cores with ordinary interleaved joints. It was decided, therefore, to carry out tests on three three-phase, 100kVA transformers of a design standard to one large manufacturer, and with cores made up of ordinary hot-rolled silicon steel, cold-rolled silicon steel of British manufacture, and cold-rolled silicon steel of American manufacture. The building losses with cold-rolled silicon steels were greater than with ordinary hot-rolled material when ordinary interleaved joints were used. Despite the increased building losses, the new materials gave much reduced losses and magnetising currents without resort to special core construction.

A Study of Domain Structures in Alnico (Ref. N/T71). By Professor L. F. Bates, F.R.S., and Dr. D. H. Martin. The British Electrical and Allied Industries Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey. Price 7s. 6d., postage 4d.—It is known that "Alnico" (Al 10, Ni 18, Co 12, Cu 6, Fe 54), when quenched from 1250 deg. Cent. in water and subsequently annealed at 600 deg. Cent., develops pronounced permanent-magnet properties. The coercivity increases from a few oersted in the quenched condition to values in the neighbourhood of 300 oersted for specimens subjected to prolonged annealing at 600 deg. Cent. The effect is known to be due to the precipitation of a metallurgical phase in the form of sub-microscopic islands. The present report records a powder-deposit examination of the ferromagnetic domain structures in four specimens of Alnico, in which had been developed coercivities of about 2 (quenched), 10, 40 and 100 oersted, respectively. The powder-deposit technique has often been used for studies of domains in soft magnetic materials and has been described for example, by Bates (1954) and Mee (1950). The patterns are formed on highly polished surfaces by fine magnetic powders deposited from colloidal suspensions, and when interpreted indicate the form of the underlying domain structure. The work was carried out at the University of Nottingham.

Effect of Low Temperature on the Stability of Permanent Magnets of Alcomax III and other Alloys (Ref. L/T 286). By A. G. Clegg, B.Sc. The British Electrical and Allied Industries Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey. Price 12s. 6d., postage 4d.—Measurements have been made of the change in magnetisation with temperature between +60 deg. and −60 deg. Cent. for magnets of Alcomax III, Columax, Alnico, 35 per cent and 15 per cent cobalt steels with a range of dimension ratios, using a magnetometer. For Alcomax III and Columax with working point below the BH_{max} point, there is an irreversible decrease in the magnetisation, otherwise the magnetisation increases with decreasing temperature. Irreversible decreases occur on the lower coercivity materials with increasing temperatures. The irreversible changes, whether due to increase or decrease of temperature, can be eliminated by a partial demagnetisation by an alternating field. The results are correlated with the changes in the demagnetisation curves of the materials with temperature.

Launches and Trial Trips

ILYA METCHNIKOV, cargo ship; built by the Chantiers de l'Atlantique (Penhoet Loire) for Sudoimport; length overall 425ft 5¼in, length between perpendiculars 395ft 8in, breadth moulded 55ft 1¼in, depth to upper deck 33ft 2in, draught loaded 22ft 4in, deadweight 6170 tons, service speed 13 knots; two complete decks, four holds, 317,800 cubic feet bale capacity, one 60-ton, one 40-ton, four 10-ton and four 5-ton derricks, electric winches; one Chantiers de Bretagne-Rateau geared turbine, 4500 h.p. at 120 propeller r.p.m., two Babcock and Wilcox boilers supply steam at 455 lb per square inch and 750 deg. Fah.—Trial, July.

SINDH, cargo liner; built by the Chantiers Navals de la Ciotat for the Messageries Maritimes; length overall 488ft 4¼in, length between perpendiculars 467ft 8in, breadth moulded 61ft 8in, depth to shelter deck 38ft 11in, draught loaded 25ft 7in, deadweight 8300 tons, displacement 14,079 tons, speed 16 knots; six passengers; five holds, 530,000 cubic feet bale capacity, one 60-ton, one 30-ton, four 10-ton and ten 5-ton derricks, electric winches; three 250kW diesel-driven generators, one 30kW emergency generator; one Burmeister and Wain single-acting, two-stroke, diesel engine built by the Forges et Acieries du Creusot (Schneider), 8300 h.p. at 115 r.p.m.—Trial, July.

LAURENT SCHIAFFINO, fruit carrier; built by the Ateliers et Chantiers de la Seine Maritime for the Société Algerienne de Navigation; length overall 392ft 9in, length between perpendiculars 361ft 3in, breadth moulded 51ft 10in, depth to upper deck 32ft 10in, draught 25ft, deadweight 5300 tons, speed loaded 13·5 knots; four holds, one 50-ton, one 20-ton, eight 8-ton and two 5-ton derricks, side loading doors, electric deck machinery, three 500kW diesel-driven generators; Sulzer 6SD.72 single-acting, two-stroke, diesel engine, six cylinders, 4000 h.p.—Trial, July.

CHEVERNY, oil tanker; built by the Ateliers et Chantiers de France for the Société Maritime des Petroles B.P.; length overall 669ft 4in, length between perpendiculars 630ft 9in, breadth moulded 86ft, depth 46ft 8in, draught loaded 35ft 1in, deadweight 32,650 tons, displacement 42,440 tons; service speed 16·4 knots; thirty oil cargo tanks, one main cargo pump room, three 1300 tons per hour cargo oil pumps; two 600kW turbine-driven alternators, one 150kW diesel-driven alternator; one C.E.M. Parsons double-reduction geared turbine built by the Compagnie Fives Lille, 15,200 maximum horsepower at 108 propeller r.p.m., 14,000 service h.p., two Penhoet P.41 water-tube boilers supply steam at 600 lb per square inch at 850 deg. Fah.—Trial, July.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., Sept., 26th.—LONDON BRANCH: London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "Some Aspects of Transistor Progress," H. W. Loeb, 6.30 p.m.

INCORPORATED PLANT ENGINEERS

Mon., Sept. 3rd.—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham, "Fan Engineering," 7.30 p.m.

Tues., Sept. 4th.—LONDON BRANCH: Royal Society of Arts, John Adam Street, Adelphi, Strand, W.C.2, "The Maintenance of Lancashire and Economic Boilers," J. H. Williams, 7 p.m.

Wed., Sept. 5th.—LEICESTER BRANCH: Bell Hotel, Leicester, "Planned Maintenance," A. F. R. Stedman, 6.30 p.m.

Mon., Sept. 10th.—DUNDEE BRANCH: Mathers Hotel, Dundee, "The Application of Work Study and Incentives to Maintenance," D. Gardiner, 7.30 p.m.

INSTITUTION OF NAVAL ARCHITECTS

Thurs., Oct. 11th.—Weir Lecture Hall, 10, Upper Belgrave Street, London, S.W.1, "Scale Effect Experiments on Victory Ships and Models," Part II, "Analysis of Wake Measurements on a Model Family and the Model Boat," D. C. Endert, Jr., J. D. van Manen, 4.45 p.m.

LIVERPOOL METALLURGICAL SOCIETY

Thurs., Oct. 11th.—The Temple, Dale Street, Liverpool, Presidential Address, W. Rose, 7 p.m.

WEST OF SCOTLAND IRON AND STEEL INSTITUTE

Fri., Oct. 19th.—39, Elmbank Crescent, Glasgow, Symposium on the Application of Low-Alloy Steels for Welded Pressure Vessels, 10 a.m.